Harper's pictorial library of the world war

HARPER'S PICTORIAL LIBRARY OF THE WORLD WAR

In Twelve Volumes
Profusely Illustrated

VOLUME VIII

INVENTIVE AND INDUSTRIAL TRIUMPHS

Science and Industry in the Struggle

HARPER'S PICTORIAL LIBRARY OF THE WORLD WAR

In Twelve Volumes
Profusely Illustrated

FOREWORD BY CHARLES W. ELIOT, PhD.
President Emeritus, Harvard University

VOLUME VIII

The Inventive and Industrial Triumphs of the War

Science and Industry in the Struggle

INTRODUCTION BY CARL SNYDER

Edited by
AUSTIN C. LESCABOURA
and
J. M. BIRD
Of the Scientific American

HARPER & BROTHERS PUBLISHERS
NEW YORK AND LONDON
Established 1817

VOL. 8—HARPER'S PICTORIAL LIBRARY OF THE WORLD WAR

Printed in the United States of America
A-U

CONTENTS OF VOLUME VIII

ILLUSTRATIONS IN COLOR

INTRODUCTION

By Carl Snyder

ONE of the most notable facts of the war—perhaps, for future times, altogether the most notable—was that it produced no towering military figure. Though it lasted more than four years; though it brought into the conflict more nations and more millions of people than had ever been engaged in any three wars before; though it was fought under the most diverse conditions, and with the most kaleidoscopic change of personnel, no Napoleon, no Wellington, no Grant, no Lee appeared. Though every opportunity seemed open, in reality little or no opportunity existed.

The explanation may be simple. The day of military genius is gone by. Military opportunity has been killed by industrialism, by science, discovery and invention. After the first few months the war became, as Lloyd George graphically expressed it, "a war of factories and not of guns and men." This is the key to the whole course of the struggle.

What was possible in Napoleon's time no longer exists. It is no longer possible to make swift and secret massings of troops; no longer possible to surprise an enemy by long and heroic marches. Secrecy and with this, to a large extent, military strategy, is dead. The actual strategy displayed in the present war was scarcely beyond that of the routine student of military tactics.

The aeroplane and the observation balloon, with the camera and the telescope, the powerful searchlights, and illuminating bombs, the telephone and radio, the long range guns, the tank, the deadly gases, the swift auto-truck,—these were the doom of the essentially military idea,—that is, a struggle of armed men. And on the sea it was practically the same. The submarine nearly, if not quite, put an end to great naval battles and therefore to great naval reputations. But for his fear of the submarine, Jellicoe could doubtless have smashed the German Fleet. But for the lack of a sufficient number of submarines the Germans could have rendered the British armada almost powerless, if not helpless. Alike on land and sea the war was a military and naval stalemate.

Germany collapsed not in consequence of military defeat, but for lack of food, of supplies, of raw materials, and because it saw that a military decision was no longer possible. When Germany unfurled the white flag, it still had more troops in the field, and these troops in excellent condition, than ever fought in all the Napoleonic wars.

All this is of momentous import. It is notorious that the prepara-

tions made by Germany for this war were of unparalleled magnitude. It had planned, studied, prepared, for such a conflict for 40 years. Certainly the German military talent was of a high order. Yet such are the limitations of human foresight that Germany had shot its bolt practically within six weeks from the war's beginning. Then it had to begin almost all over again, build from the bottom, even as did France and England and the other nations. If it had not been so, Germany would have won. It is not unreasonable to expect that no nation will ever again make such preparation, because it is now clear that a modern war requires vastly more than great armaments or the mere drilling of troops. Preparations, to be effective, would have to be on too prodigious a scale to be politically feasible.

Towards its end the war became more and more simply an industrial struggle. It was not a question of infantry or artillery, but of the volume of ammunition, the number of tanks and aeroplanes and the quantity of destructive gases, the number of submarines or destroyers which could be put into the field or on the seas. And because the Allies, with America behind them, outranked Germany two to one industrially, the German cause was hopeless.

The greatest achievement of the war was probably the submarine. If Germany had spent as much on her submarines as she had spent on her all but useless navy, she might and probably would have won the war. She could have won it by cutting off the Allies' supply of food and of munitions from America. If America could have been kept out of the war, completely isolated, the fortunes of the struggle might easily have been reversed, for industrially Germany far outranked her chief Allies. It was indeed fairly clear at one time that Germany was winning. It was only because the destroyers, the depth bombs and the convoys were able to cut down the terrific destruction of ships that the Allies were saved.

The next greatest achievement probably was the overcoming of the submarine by means of swift destroyers, the depth bomb, torpedoes and the convoy system. Towards the close of the war there was developed a new type of destroyer able to make 50 to 60 miles an hour. On a voyage of 250 miles against wind and weather one of this type actually made an average running speed of 32 miles an hour.

Destroyers of such range and speed would probably be fatal even to the finest and swiftest type of submarine that could be built. It seems fair to say therefore that the submarine menace is past. This was one of the very great fruits of the war.

The next most powerful or effective weapon of the war was the aeroplane, and all that it meant. There were plenty of times when Germany had the troops so that if they could have been concentrated secretly and swiftly they might have been able to drive a wedge through the Allies' positions and cut off communications between France and England. This might not have been fatal to the Allied cause, but if it had come along with the success of the submarine, it would have profoundly affected the Allied morâle. In some measure, the same thing

was true for a time of the Allied forces. While Russia was still in the war and helping the enemy on the Eastern front, an effective concentration of troops in Napoleonic style might have driven a similar wedge far into the German lines. The aeroplane therefore was one of the modern inventions which went far to change the whole art of warfare.

The development of modern sea transport was another. If Napoleon could have put an army across the British Channel possibly one-tenth as large as America was able to put across the whole width of the Atlantic Ocean, history in his time might have been changed. It was to Napoleon that Robert Fulton first offered his steamboat. A trial vessel constructed on the Seine, failed to arouse the interest of his engineers and so far as we know, of Napoleon himself. To-day a fleet of 50 ships, the modern representatives of Fulton's frail vessel, would suffice to carry across the Channel a large part of Napoleon's army at its height.

The feat of carrying across the seas and of maintaining there over 2,000,000 men from America was without parallel in military annals. The wonder of it is sufficiently attested by the fact that Germany did not believe it could be done. It was done, and this was perhaps the decisive factor in the outcome. The meaning of this for the future and for the whole world is immense. Henceforth, a mere European alliance is worthless if but a single one of the countries could engage the support of a powerful ally, though it be 3,000 miles away.

The ships that made this possible could not have been built for military purposes alone. They were purely an industrial product and purely an industrial triumph. So with many other phases of the war. The vast output of high explosives, of gases and of war materials of every variety, to say nothing of food and supplies, was made possible by the development of modern factories, of modern mining, of modern railroading and of the steel industry. The gun that hurled a shell 70 miles from the German line into Paris was distinctly an industrial and not a military product. If Germany had not become the great steel-making nation in Europe, such a weapon would never have been thought of, let alone designed and constructed.

And yet this war, like all wars, was fought along lines apart from the inventive and scientific possibilities of our day. For the first two years it was still, in type, a military war. This is only saying that the military mind has a high degree of conservatism and clings to the models of the past. A classical example was that of Fulton's experience with Napoleon. Another instance was the long delayed adoption of the Monitor type of ironclad which played such a striking rôle in the Civil War. It is said that von Tirpitz, who at least gained credit for a large part of the period of "frightfulness," was a determined opponent of the submarine up to a few years before the war.

Looking back at it now, it seems almost incredible that millions of men could have been held stretched along a long thin line of trenches, throwing hand grenades at each other to break the monotony, and that

this could have endured for almost four years. Only the military mind was capable of such a deadlock as that. Towards the close of the struggle, purely military men had begun to give way to the engineering and inventive type. If the war could have lasted for but another year, the result might have been so decisive and, indeed, so frightful, that the whole world would have agreed never to tolerate another war.

It is said upon good authority that the United States had, when the armistice came, sufficient quantity of a new and super-deadly poison gas to exterminate the whole German army and the people of many German cities besides. It is claimed that a few tons of it could have asphyxiated all Berlin. This new gas could have been carried by aeroplanes and would have meant that forts and trenches would have been as futile a protection as a pasteboard fence.

For another thing, we were building, when the war ended, aeroplanes at such a rate that we could have utterly overwhelmed the German air fleets and, as the picturesque phrase goes, "put out the eyes" of the German army. We were likewise building tanks at an extraordinary rate, and the possibilities of this new weapon of offense had as yet hardly been touched. Incidentally, it might be remarked that the reputed foresight and adaptability of the German army-heads was not disclosed in any of the later phases of the war. The submarine was their one great effort. They failed completely to realize the possibilities of the tank, and so far as we know German science yielded no such superlatively deadly gas as that developed in America. Nor, for that matter, did German medical science shine particularly. It was slow in adopting the new methods of inoculation against typhoid, and in general it is asserted that the health of the Allied armies was superior to that of their foe.

When we turn to the other side, the contributions of the war to science, invention or industry, it must be confessed that these were surprisingly few and far between. The war did much undoubtedly to develop the aeroplane. It probably compressed ten years of progress into four. But it added nothing essentially new. In other fields it borrowed grudgingly from other inventions, but gave few in return.

On the other hand, the war all but, one might say, asphyxiated science while it lasted. The larger part of research in the chief nations was practically suspended. Almost no great discovery spaced the long, dull, brutal, savage struggle. Physically and mentally the war was essentially a regression to a lower stage of human culture. It was a kind of international neurosis. The effect for the time it lasted was to stifle inquiry, progress and intellectual freedom.

But this is not saying that this effect will be other than temporary. Our Civil War at least seemed the prelude for an immense burst of almost unparalleled energy and activity in the United States. To some extent, the same thing was true in Germany and partially also in France after the Franco-Prussian War. It may be that the same thing will take place now. It is yet too early even to suggest in what direction this activity may be most fruitful. Unquestionably, the aeroplane will

soon become more or less of a commercial factor. But to what degree it seems now difficult to determine.

Towards the end of the war this country had developed a remarkably fast and efficient aeroplane, practically as fast as any that has ever flown; its record was about 140 miles per hour, and it could carry practically double its own weight. This was a very great achievement, and may mean much for the future. It is obvious that if the aeroplane becomes a great factor in transportation almost the whole question of military offensive will be literally transferred to the air. The most powerful military nation will be, obviously, that nation with the greatest number of aeroplanes and aero-factories and with the greatest industrial wealth behind it. Armies will be all but useless when a single flyer, in a single flight, can carry enough bombs of deadly gases to choke to death half the population of New York, London or Paris. That will be, so to speak, the "reductio ad absurdam." Civilization could not tolerate such a possibility.

The development of water-craft capable of attaining 50 to 60 miles per hour, for long stretches, will, with the perfection of the aeroplane and the hydroplane, mean most unquestionably the doom of the submarine. They will almost unquestionably mean also the doom of great battleships and "dreadnoughts." But whether the political and military powers will have sense enough to see this is another question. This is another item to add to the regrets that, however frightful was its toll in life, and its cost in money, the ending of the war, coming when it did, was little short of a calamity. Two years more of it, and there would have been no hesitation in any land as to the desirability of a League of Nations.

But it may be that the steady and irresistible march of invention and industry will bring this more surely than any possible political covenants or "scraps of paper." Altogether it seems certain that we may face the future with serenity and content. Even in this horrible recrudescence of the war-spirit, civilization did not fail. It is not now menaced. We now know to a certainty that the militarist belongs to a past age, and almost to another world. It is deeply to be regretted that the hydra-headed monster of hate and spoliation could not have been given its deathblow. But even as it was, this much at least remains; that militarism finally, unescapably, and we may say, inevitably *failed.*

That is undoubtedly the great and lasting inventive and industrial triumph of the war. If this could have been gained in no other way, it was worth all the blood and treasure it cost.

Inventive and Industrial Triumphs

Inventive and Industrial Triumphs of the War

PART I. THE WEAPONS OF ARMED MILLIONS

WHY POWDERS EXPLODE AND CANNON SHOOT

A Brief Statement of the General Principles that Support the Use of Powder and Projectiles

A ROUND of ammunition, for any kind of gun or small arm, consists of a primer, an igniter, a propelling charge, a projectile, a fuse and a bursting charge. A cartridge case is frequently added to tie these members together into a single unit, which is then known as fixed ammunition. In rapid work with any kind of a gun this is a great advantage; with hand or shoulder arms and the smaller sizes of gun it is necessary to have the ammunition in this shape. The dividing line falls about in the 3-inch class; it may be stated, as a general proposition, that for this and smaller sizes fixed ammunition is always used, while it finds occasional application up to six inches. Beyond the latter size the powder of the propelling charge is done up in bags and handled independently of the projectile proper.

EXPLOSION VERSUS DETONATION

Naturally the part on which greatest interest centers is the explosive. Whatever substance be employed for this purpose, it owes its explosive power to its ability to expand with great rapidity on changing from the solid or liquid form to the gaseous. The energy depends upon the heat evolved in the explosive reaction; but the *power* is the rate of producing energy, and so depends upon the time in which this reaction takes place.

Whether combustion be rapid or slow, it proceeds along the same general lines. The mass of powder can burn only after it has reached the ignition temperature. The heating of the general mass is brought about by the burning of the portions that are first ignited. The more rapidly the mass is heated the more rapidly it burns; the speed of heating depends in last analysis upon the pressure. The action is an explosion for ordinary speeds of burning. But theoretically, the speed at which the powder takes fire and burns up can equal the velocity of projection of the molecules of the gas. It can never exceed this, and practically, of course, there is here only a limit which it can approach and never equal. When it does approach reasonably close to this limit, we have detonation, as distinguished from mere explosion.

Any explosive most be confined to some extent in order that it may build up the necessary pressure to get up to speed. But when the velocity of combustion attains a high value, no further confinement or assistance need be given; here the inertia of the gas generated is a sufficient approach to actual confinement to keep the pressure up to the mark in the zone of active combustion. Many explosives

cannot be made to detonate at all, since the necessary pressure is altogether too high; such substances will explode effectively, however, and the time element involved in explosion as distinguished from the practically instantaneous detonation enables their activities to be controlled. Other compounds will not detonate of themselves, but can be detonated by means of an explosion of a secondary substance, which provides the requisite pressure. And, finally, there are some explosives that will invariably detonate, even when they are merely lighted in the open.

An explosive compound is always a nitrogenous one. The heat of formation of such compounds is very low, algebraically speaking, making the heat of dissociation high; and the stability is likewise low. Ordinarily the nitrogenous compound lacks sufficient oxygen for complete burning, and this has to be supplied if possible. If it cannot be supplied, it may be that such combustion as is possible will still lead to a powerful explosion; no less an explosive than T. N. T. is deficient in oxygen by over 60 per cent.

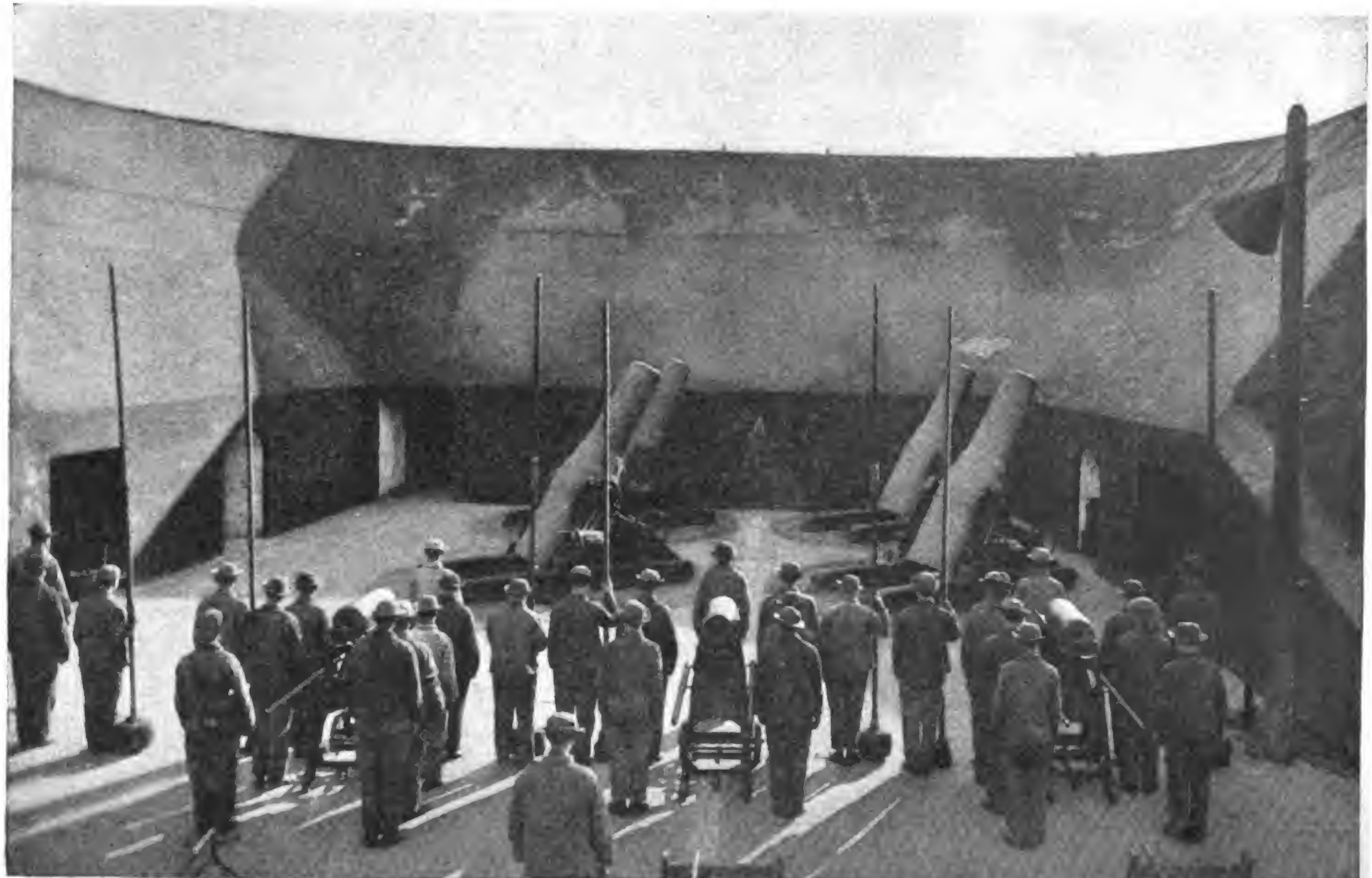
An explosive mixture, in distinction from an explosive compound, is a physical or mechanical mixture of explosive compounds and oxydizing agents. It usually represents an effort to bring to an explosive compound which is deficient in oxygen, a source of supply of that element of sufficient magnitude to support complete combustion.

Black powder is the original gunpowder, and by the same token the original explosive. It consists of pulverized charcoal, sulphur and saltpeter, and is therefore a mixture. The sulphur and charcoal are inflammable, and will burn just as fast as oxygen can be supplied to complete the combustion. The saltpeter fills this requirement; when it is heated, it gives off oxygen. Heat is applied externally, the saltpeter gives off oxygen which burns the adjacent sulphur and charcoal; this leads to the evolution of more heat, which leads to further burning, and so on to the end of the charge. Not having to wait for air or anything else to be supplied, the combustion spreads through the mass with extreme rapidity—though of course not with the speed of a detonation. The sulphur combines with the potassium in the saltpeter to give a solid residue which passes off as dense white smoke; the rest of the combustion products are gases, which demand many times the space occupied by the original components of the powder. They expand rapidly in the face of any ordinary pressure or confinement, driving something before them—the projectile in ordinary practice because it is least firmly anchored, or the weakest portion of the surrounding surfaces in the case of accidental explosion or blasting. From the physicist's point of view, it cannot be too strongly emphasized that this is all that an explosion amounts to—a mass of suddenly formed gas, rushing to occupy the space which it requires, and sweeping things before it in doing so. When we confine it in a gun barrel, there is only one direction in which it can rush; and it rushes in that direction, pushing the projectile before it faster and ever faster until the end of the bore is reached and a free vent attained.

GUNCOTTON AND SMOKELESS POWDER

For centuries there was no material improvement made on gunpowder. But the discovery of guncotton in 1846 was decisive in this direction. Guncotton is not a mixture, but rather a compound. It is cotton which has been subjected to the action of a mixture of nitric and sulphuric acids. It looks much the same as it did before; but the sulphuric acid has extracted some of the water from the molecules of the cotton fiber, and the nitric acid has replaced this by oxygen. The resulting combination is a solid, but unstable, because its molecules consist of atoms which could easily be rearranged into several molecules of stable gases. If the guncotton gets a shock of just the right sort this rearrangement takes place, and is propagated through the mass in a sort of wave, much after the manner in which a sound wave passes through air. This velocity of detonation—for here we *have* detonation—is from 16 to 20 thousand feet per second; and as in the case of simple gunpowder, the gases that result from the action occupy many times the space of the original solid.

At first guncotton was not very useful because the detonation could not be controlled; it was continually going off by accident and shattering guns and everything else in sight. But it was finally discovered that wet gun-



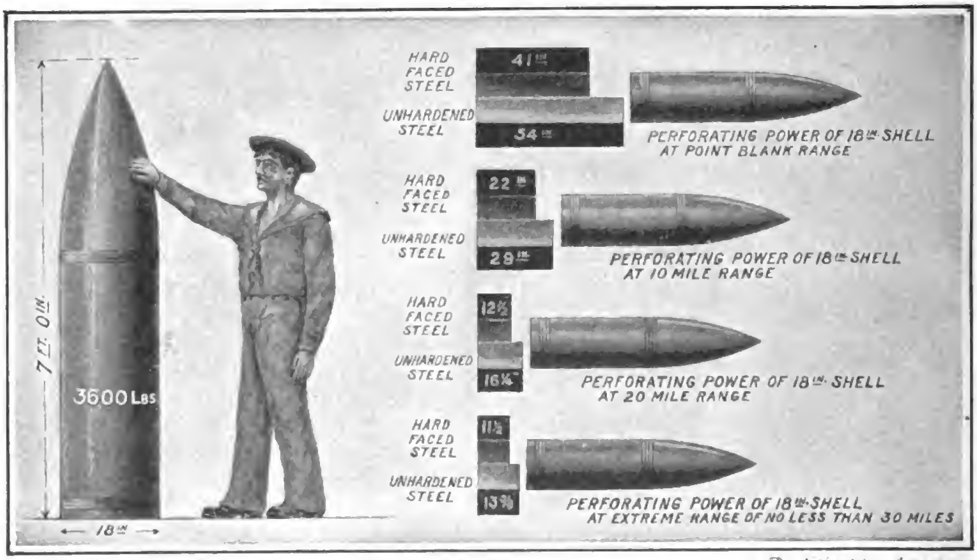
© Logan. Courtesy of Leslie's Weekly.

Mortar Battery Ready to Fire

In the foreground are the 12-inch shells mounted on trucks. The guns are short but have a high firing angle which gives them a long range.

cotton could not be ignited at all, and hence could be kept in perfect safety, while the addition of a trifle of dry guncotton as a primer would make its detonation possible again.

Now guncotton burns with extraordinary rapidity. It is claimed that if a bit of black powder is placed on a small sheet of guncotton and the latter ignited, it will burn out from under the powder so fast that the powder will never catch fire at all. This fast-burning quality made guncotton unsuitable for use in guns. But it was eventually discovered that acetone would dissolve the guncotton; and that after drying out this solution, a hard, horny substance is obtained, which burns with comparative slowness, and cannot be detonated at all. This is the ordinary smokeless powder, of which we hear so much nowadays. You can light a "grain" of smokeless powder—which would be called a block of powder by a layman—and it will burn brightly, about as fast as celluloid. If you wish, you can light it and blow it out again. But when you light it in the confinement of a gun, it burns much faster because the pressure and heat are confined; and this means explosion.



Shell of the Largest British Naval Gun

POWDER ECONOMICS

The size and shape of the smokeless powder "grain" are based on the fact that when the powder is ignited, it burns only on the surface. The larger the exposed surface, the faster the grain burns. So in order to give a larger burning surface, the grains are pierced through with holes from end to end—usually seven of these, arranged one in the center and six around it at regular intervals. When such a grain is ignited, the outer surface not alone burns, but likewise the surfaces of the holes. As the outside of the grain burns away, this surface diminishes in area; but as the inner surfaces of the holes burn away, they increase in area. These two factors may easily be made to balance each other and keep the burning surface of the grain nearly constant until it is finally consumed. The practical effect of this is to enable the powder to give off gas at a constant or even an increasing rate, and so keep up the push on the projectile as it passes along the bore of the cannon. The size of the grains for any gun should be just sufficient to allow the powder charge to be completely consumed at the instant the projectile leaves the cannon. If grains of too large a size are used, they will not be burned up in the necessary time, and that portion which burns after the projectile has departed is wasted. If the grains are too small, on the other hand, they may burn so quickly as to give off all their pressure at once and burst the gun.

Courtesy of Scientific American

Hoisting Guns up the Holy Mountain

During the war the Italians covered Monto Santo with guns from this vantage point, destroying division after division of Austrian troops entrenched in the solid rock of Monte San Gabrielle, which stood between the supreme command of the Italian armies and Trieste.

The British make their smokeless powder a little differently. They dissolve guncotton in nitroglycerine instead of in acetone; and they press the resulting stiff paste into strings or rods. From its shape this is called cordite. It makes good powder, but it is more erosive than that made in the United States. This is largely because of its excessive heat of explosion—heat in far greater quantity than is needed for the purposes in hand, and which can only be used up on the interior of the gun. This excessive heat, in turn, seems to be due to the nitroglycerine present. This is a light yellow, oily liquid made by the action of a mixture of nitric and sulphuric acids on glycerine. It is among the most dangerous of explosives.

Perhaps the most extraordinary of the common explosives is T. N. T., or, to give it its full name, trinitrotoluol. This is made by the action of the two acids just named on toluol, a coal-tar product. It is a violent explosive, but a very safe one because it will hardly detonate without the aid of a strong fulminate cap. It cannot be exploded by friction or shock or fire. If ignited, it burns with a black smoke; it can be fired into from close range with a rifle without detonating.

EXPLODING AN EXPLOSIVE

Primer compositions, used to set off other explosives, are invariably mixtures, because whatever else their characteristics, they *must* have all the oxygen they can use. They usually have an explosive compound as a base, and ordinarily this is mercury fulminate. The addition of potassium chlorate increases the sensitiveness and supplies oxygen—the fulminate itself is deficient in this. This almost doubles the amount of heat available but at the same time prolongs the action considerably—even with more oxygen to do it, you can't expect to burn a thing completely up as fast as you could have burned it half up. But this is no drawback at all; in fact, in primers a bit of slow action helps along the ignition of the main charge. So true is this, that ordinarily there is added some antimony to slow the action still further.

The priming may be done by ignition, by friction, or by percussion. In friction primers the compound contains some ten per cent. of ground glass. A serrated plunger is drawn through the composition, and the resultant heat of friction between the glass and this rough surface generates enough heat to ignite the composition. The percussion primers are set off by the blow of a firing pin, the action of which is retarded by the composition, converting the mechanical energy of the pin into heat which is sufficiently localized at the point of the pin to reach the temperature at which the composition will ignite. The anvil primer is one example of this which may be seen in any .32-caliber revolver cartridge. The composition here is shallow and the firing pin blunt to insure its contact with enough of the composition to get a spark that will ignite the latter. The stab primer is more common in artillery fuses for bursting shell. Here the composition has considerable depth and is covered with a thin metallic disk to confine it. The sharp point pierces the disk and must then be completely retarded by the composition, which has to be thick enough for this purpose. The pin is not sharpened to a razor edge, and its energy per unit area of front is sufficient to make it a very reliable means of priming.

Explosive	Temperature of explosion	Volume of gas at temperature of explosion	Heat of explosion	Pressure exploding in own volume	Velocity of detonation	Power of explosion
	Degree Fhr.	cu. ft.	B T U	bs. per in.^{2}	Ft. per sec.	Horse-power
Trinitrotoluene (T.N.T.)......... $C_7H_5(NO_2)_3$	4500	157	1320	240,000	23,000	200,000,000
Mercury fulminate.. $C_2N_2HgO_2$	6300	69	660	250,000	16,300	95,000,000
Smokeless powder.... $C_{24}H_{30}(NO_2)_{10}O_{20}$	5000	158	1750	216,000		
Black powder...... $16KNO_3+21C+7S$	4700	43	1210	125,000		
Illuminating composition............. $3Ba(NO_3)_2+10Al$	17,700					

PRESSURES, TEMPERATURES AND POWER

The results of exploding one pound of several standard explosives are set forth in the table herewith. The temperatures are seen to be high as compared with the usual temperatures met by the engineer; they are insignificant enough, however, when compared

with some of the stars, whose temperatures run from 10,000 to 70,000 degrees. The volume of gas generated, if reduced to a standard temperature, is not extraordinarily large. The heat of explosion is low enough if compared with the heat of combustion of some ordinary fuels. The pressures developed, while high indeed, can be exceeded by other means. The velocities of detonation are high, as velocities under human control go. But the amazing thing is the power developed. It seems inconceivable that a single pound of T. N. T. can yield two hundred million horsepower. It will be seen that this result comes, not from the amount of energy developed, which is ordinary, but from the very remarkable intensity. The infinitesimal interval of time in which the energy is brought out makes the power tremendous, for power is the rate of doing work and increases as the time is cut down.

Let us turn again to our round of ammunition. We have the primer, which is set in action by the impact of the firing pin. This in turn ignites the black-powder igniter, developing a large volume of gas at high temperature and good pressure to drive deeply into the smokeless powder and thoroughly stir up the grains, thus insuring prompt inflammation of the entire charge. In small guns the igniter is combined with the primer; in large guns it is put up in several small bags and distributed throughout the propelling charge. Its presence is necessary because, as already indicated, smokeless powder burns feebly at atmospheric pressure, though its combustion increases rapidly with a rising pressure. Black powder, on the other hand, burns so vigorously at atmospheric pressures that it is not safe to light it in the open.

The combustion products of smokeless powder are deficient in oxygen, and their contact with the atmosphere at the muzzle greatly increases the muzzle flash. For this reason machine guns and the smaller types of artillery pieces use flash shields. Smokeless powder may not betray itself by smoke, but it does by flame. The muzzle flash is blinding, and at a distance behind hills and forests it is as bright as sheet lightning. It is interesting to note that in guns up to 100 calibers in length the muzzle blast has an accelerating influence on the projectile.

WHAT HAPPENS INSIDE THE GUN

All lots of powder are proved by ballistic test before acceptance. This test consists in obtaining the maximum pressure developed in the gun bore and the velocity imparted to the projectile. The pressure is found by means of a crusher gauge, consisting in general terms of a hard piston that can be driven against a soft copper cylinder. From the deformation of this cylinder the pressure is calculated. In modern guns it is found that pressures run from 15 to 25 tons per square inch. The muzzle velocity is found by allowing the projectile to pass through two wire screens in electric circuits, and timing it in hundredths of a second between them. Muzzle velocities of big guns run from 1,700 to 2,700 feet per second.

It is desirable, as already suggested in speaking of nitroglycerine, to develop the required gas volumes and pressures from the propelling charges at the lowest possible temperatures, in order to minimize the tremendous eroding effect which the hot gases have on the bore of the gun. This erosion is serious. It allows leakage of gas past the projectile, as well as destroys the rifling. Thus, with small arms a sharpshooter will not use a rifle for over 3,000 rounds, because of the loss of accuracy resultant upon wearing of the grooves and lands. In machine-gun work, however, the tube is usually good for 100,000 shots or more. The useful life of large guns, on the other hand, may be as low as fifty rounds. In any event, the demands are contradictory, because we need temperature to produce good pressure behind the shell. However, it is at least possible to see that we do not develop more temperature than is necessary.

All modern guns are rifled. In the smaller calibers there is usually a uniform twist of about seven degrees. The larger calibers are given a gradually increasing twist, running from one turn in fifty calibers to one in twenty-five. This is so that the inertia of the shell against a turning movement may be gradually overcome.

The bore of a gun is the inside diameter of the lands or ridges of the rifling. In medium caliber guns the grooves are several hundredths of an inch deep, and the diameter of the copper driving band is again several hun-

dredths greater than this. So it can be seen that it will take considerable force to make the band conform to the bore. The object of the driving band is twofold: to check the escape of gas and to bite into the lands with a soft metal that *will* bite, and thus make rotation certain.

There are two main types of shell, shrapnel and high explosive. The former uses a fuse set to burst above the enemy so that the cone of dispersion of the balls will scatter them at the rate of about one per square yard. The high-explosive shells use both time and impact fuses. The present war is the first one in which high explosive shells have been extensively used; and their destruction is tremendous. When we look back at the statement that a single pound of T. N. T. will disrupt the strongest gun, and then reflect that a good many pounds of such an explosive can be got in a single shell, we can get some slight notion of what happens when one of them strikes. It is this development which makes it in order for us to talk about the detonating explosives in the present chapter; for if we were interested only in propelling charges they would obviously be ruled out as incapable of being sufficiently controlled.

GETTING THE RANGE

How the Modern Artillerist Works Out the Problem of Sending His Shells Where He Wants Them to Go.

CLOSE one eye and then bring the tip of the index finger down upon any small object within reach and at about the level of the open eye. A man who has never tried this experiment will be astonished to find that his finger may overreach or fall short of the object by as much as an inch or more, and yet using both eyes he could act with such accuracy as to bring two pinheads together at the very first attempt. This shows how much we depend upon triangulation for the judging of relative distances. With a camera one may gauge distances up to one hundred feet or so by carefully noting the length of focus necessary to produce a sharp image on the ground glass. Similarly, with the naked eye, we may estimate short distances by the change of focus in the eye itself; but for greater distances we have to utilize the principles of triangulation employed in range-finding.

In a loose sense of the term we are all cross-eyed most of the time. In order to see an object, the eyes must converge or turn in so that the optical axes will cross upon it. The nearer the object, the more they may turn in. It is only when "day dreaming," or looking at an object an indefinite distance away, that the optical axes are strictly parallel.

Harking back to our school days we recall that the triangle is a figure with which much mathematical juggling may be done. It possesses three sides and three angles, and if any one side and any two of the other five elements be known, the whole triangle, no matter what its shape, can be reconstructed, and the size of every angle and side be determined. Whenever we look at an object we solve unconsciously a problem in trigonometry. A triangle is formed, with the eyes at two corners and the object at the third. The base of the triangle is the distance between the eyes, and the convergence of the eyes gives us two angles at each end of the base. No one bothers to find out the length of this base line or the value in degrees of the two angles, but by long practice every one has acquired an ability to gauge the triangle by unconsciously testing the muscular strength required to train the eyes upon the object. While few of us have learned how to gauge actual distances, we can all sense the relative sizes of triangles with such precision that, for objects within a short range, we can tell to a sixty-fourth of an inch whether one object is nearer to us than another; because in looking from one object to the other there is an infinitesimal contraction of the angle of convergence. The actual change in this angle is measurable in

seconds of arc, and yet we can feel and gauge the slight tug of the muscles necessary to swing the eyes through this minute angle.

INCREASING THE DISTANCE FROM EYE TO EYE

The reason the change of angle is so small is because the distance between the eyes is but one-fifth of a foot. But what if we had a broader eye-base? If our eyes were set apart as far as an elephant's, how much more distinctly would distant objects stand out in relief? What if we used some artificial means of virtually spreading them apart a dozen feet or more? That is what the modern range-finder does, and it is also equipped with means for measuring the convergence necessary to train the gaze upon a distant target. With a base line of fixed length and the measure of the two angles at the ends of the base known, it is then a simple matter to reconstruct the triangle formed between the range-finder and the object and to determine the distance of the object from the range-finder.

The usual range-finder consists of two telescopes with a single eye-piece. The telescopes run at right angles to the eye-piece and in opposite directions. By varying the positions of a number of prisms within the telescopes, the light rays entering each telescope can be more or less bent until the rays coincide, indicating that the instrument is properly adjusted for the target. The observer watches the images appearing in the eye-piece until they coincide. A micrometer device measures the amount of rotation necessary to produce this result; but, instead of giving the measurement in degrees, it is calibrated to give the linear distance of the target from the range-finder. The calibration may be seen through the second eye-piece which, by means of a pair of prisms, is brought to bear upon the micrometer scale.

Of course, the longer the base line of the instrument the more efficient it is. Range-finders used on ships may use a base line a dozen or more feet in length, but for field service this would be entirely too bulky. The ordinary portable range-finder has a base between three and four feet long. In the case of fixed artillery in forts, ranges are found by placing observers a mile or more apart, and connecting them by telephone or telegraph in such a way that they may make simultaneously observations from each end of this long base line and report to a common chart room where angles are worked out and the position of the target determined with a wonderful degree of accuracy.

Range-finding has been reduced to such a science that it is necessary to conceal batteries or guns. The battery must be kept out of sight, and it must fire at an enemy who also

Courtesy of Scientific American.

Training the Eye to Judge Angles

Here artillery students are learning to locate smoke puffs on a miniature landscape.

remains out of sight. The man who directs the firing may be at a great distance from his battery, located at some point of vantage, where he may obtain the range and signal it to his gunner. Knowing that at any moment he may become the target of the enemy's fire, and realizing the accuracy of modern artillery, it is very necessary for him also to remain concealed in so far as is possible. A system similar to that of the submarine periscope was employed in the German Army, so that a man hidden behind a natural breastwork might raise his artificial eyes far above him.

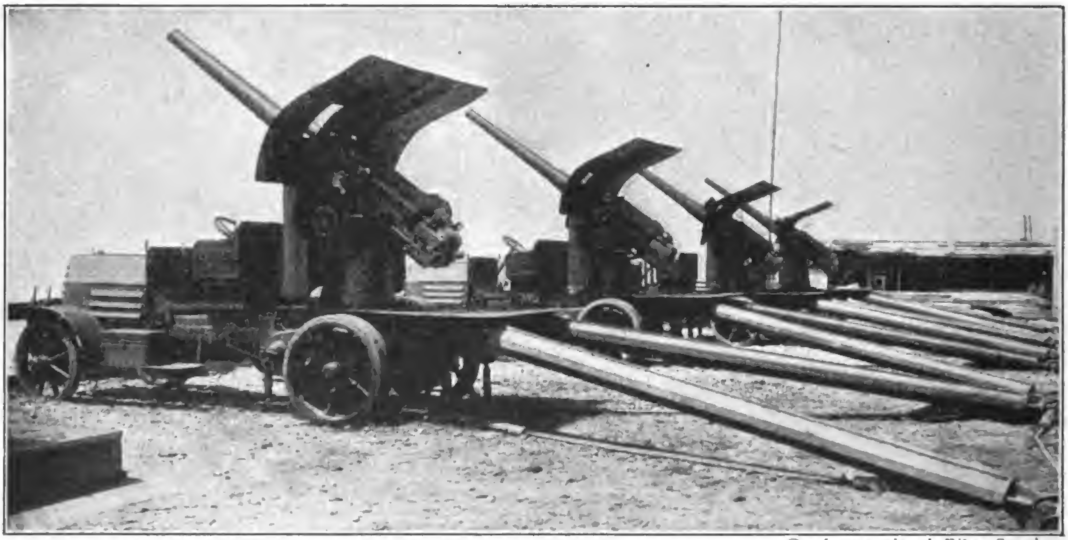
Even the top of the periscope has been frequently disguised by wisps of straw, so that it is next to impossible for the enemy, at the enormous range of modern fighting, to discover its whereabouts.

THE RANGE AND THE GUN

After we have the range of the enemy, we still have before us what, so far as the mathematics required in its original solution is concerned, is by far the more difficult part of the problem. It is necessary for us to direct our gun so that it will hit the mark. Now the man whose experience with firearms is confined to a little revolver practice may not realize that the trajectory or path of every projectile is a curve, but this is none the less true. Two forces are acting on the bullet or shell from the moment it leaves the muzzle of the rifle or gun. One of these is the forward-driving force of the explosion; the other is the downward-acting force of gravity. The fact that the projectile is moving forward does not affect in the least the gravitational pull upon it; in fact, if a rifle be set up horizontally and one bullet shot from it while the other is dropped from the muzzle, the first will hit the ground a mile or two away at precisely the same time with the one that hits the ground beneath the muzzle.

It is plain enough that a projectile thus shot horizontally is going to hit the ground somewhere; and consequently it is plain enough, when we come to think of it, that it travels, not in a straight line but in a curve. When we fire at a reasonably tall object at a reasonably close distance, we are not much interested in the distance to which the bullet would go before coming to the ground. But when we fire at a target a long distance away, we are compelled to take into consideration the drop of the bullet and fire more or less up in the air, so that the bullet will come down nearly where we wish it to, and in coming down strike our target.

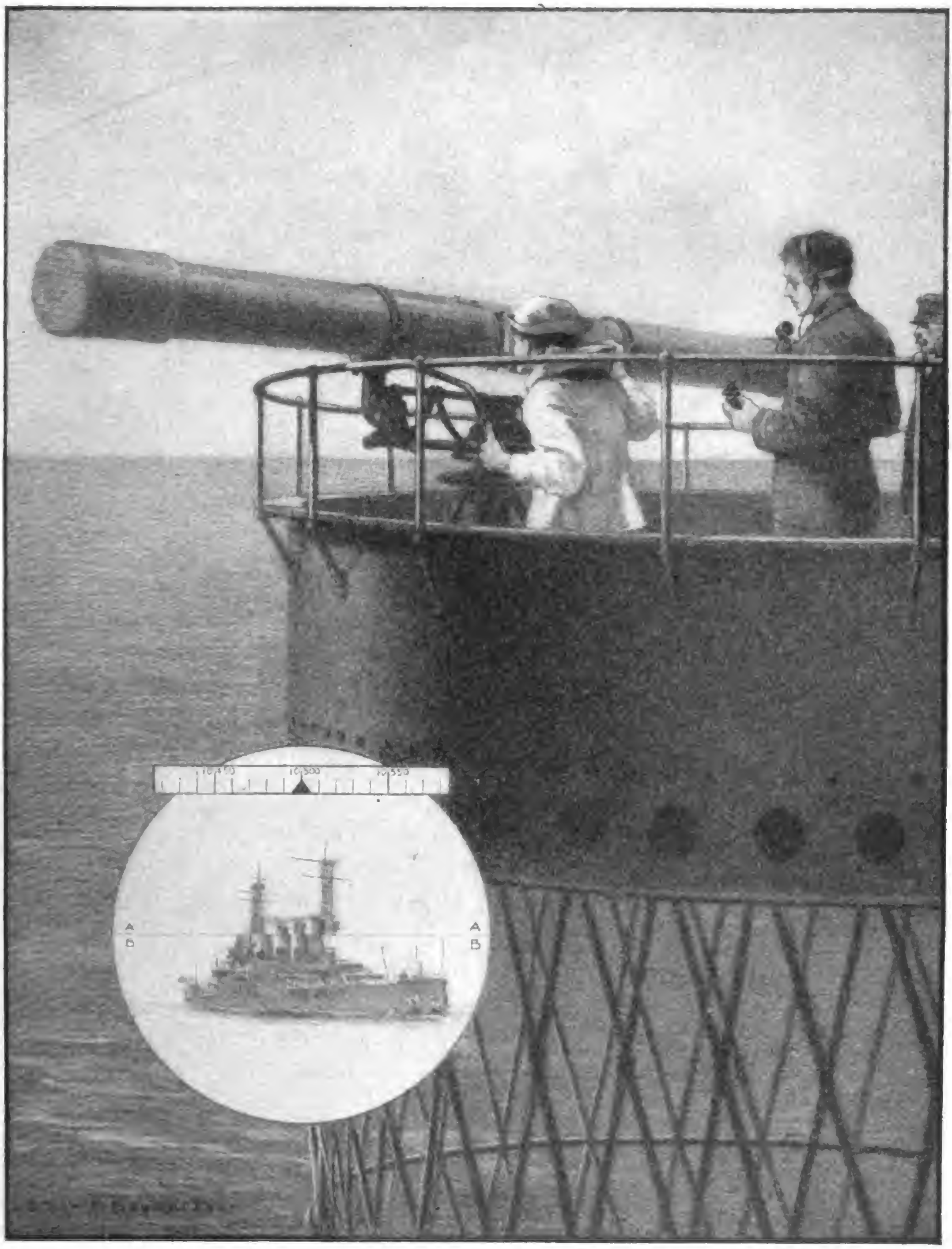
In general terms, the distance at which a projectile will strike the ground, or its range, depends upon two things—the force exerted upon it by the powder (which is another way of saying the initial velocity) and the elevation of the gun. Put more force behind the bullet, so that its starting speed is greater, and it will go further. Elevate the gun a little, and it will also go further—up to a certain point. If there were no air resistance, the maximum range would be got with an angle of elevation of 45°. With the air to retard, there is very little choice between the angles



© *International Film Service.*

Battery of Italian 102 Guns

These anti-aircraft guns were used with great effect against the Austrians on the Italian Front.



Range-Finding

Finding the range in the fighting top of an American battleship. What the operator sees is indicated in the insert. The field of sight is divided into halves, and the target is split into an upper and lower half. The operator must register the upper part with the lower part, and then get a reading in yards on the scale.

$43\frac{1}{2}°$ and $46\frac{1}{2}°$; either may be spoken of as giving maximum range.

Likewise, if there were no atmosphere to retard the projectile, it would be a matter of ridiculous ease for the mathematician, given the initial velocity and the weight and size and shape of the shell, to predict exactly where it would strike. But unfortunately we are compelled to practice artillery work under atmospheric conditions; no means has yet been discovered of inducing the enemy to take up his position in a perfect vacuum while we shoot him up. And this introduces a complication.

No precise way of dealing with the resistance of the air has ever been discovered, and it seems pretty well demonstrated that none ever will be. In the language of the mathematician, it is not possible to separate the variables in the integrations that have to be performed, or to express the resistance functionally in terms of the velocity. The resistance of the air does change as the velocity of the shell changes; we can determine what it is, by direct observation, for various velocities; but that does not help us except in giving us the material for making a very close approximation of the shell's flight. This approximation, however, is plenty close enough, so after all the question is more or less an academic one.

THE CANNED MATHEMATICS OF THE BATTLEFIELD

Well, then, we know how much powder we are using behind a shell, and we know the size and weight of the shell. This means that we know its initial velocity. We then proceed to construct a table showing how far it will travel, before striking the ground, for angles of elevation from zero to 90 degrees, making the intervals in this table one degree or ten minutes or any other value which we please. Then when the range-finding service tells us that the object which we must hit is 5 miles away, we are able to elevate the gun so that the shell may drop right on that object. In other words, the gunner in the field does not have to deal with the mathematics at all; he has a range table in which all the necessary mathematics has been canned for his convenient use.

© International Film Service.

The New Telescopic Sight Now Used in the United States Field Artillery

In fact, the canning of mathematics for the benefit of the gunner goes further than this. If the range table tells him to elevate his gun 16 degrees, he must have some instrument about the gun which tells him when this elevation has been attained. And just as the range-finder registers angles and records the corresponding distances, so the scale connected with the elevating mechanism of the gun is graduated in yards or miles instead of in degrees. If an angle of elevation of ten degrees gives a range of three miles, the point on this scale which corresponds to the elevation of ten degrees is marked, not ten degrees at all, but rather three miles. So the gunner never has to consult the book at all; the mathematics is canned in the book, and the book is canned all over again on the gun.

The guns that are used for firing at a visible target introduce still another element of rapid work. There is a hindsight and a foresight; and it is obvious that the relative position of these is changed as the gun is elevated, so that there is a definite connection between their relative position and the distance of the target. To take advantage of this fact, the hindsight is made in the form of a long, straight or circular bar, projecting upward from the top of the barrel at the rear; and this bar is graduated. Then the gun can be elevated visually; if the target is 2,500 yards away, the 2,500 mark on the rear sight is aligned with the front sight and the target, and the gunner then knows that he has got the gun pointed so it will hit the target at that distance. As a final consideration, if he is shooting over an obstruction at an invisible target whose range has been given him, he can align the foresight horizontally with the proper mark on the hindsight by means of a spirit level. So far as the man at the gun is concerned, the whole business of ranging and aiming is entirely mechanical.

Now it is necessary to foretell the range; but there may be an error made in so doing, hence it is likewise necessary for the observer to confirm his estimate by watching the actual effect of the fire of his guns. He may find that he has underestimated the distance of the target and must signal to have the guns elevated accordingly. For such purposes a range-finder is not required, but field glasses may be used; these, also, are arranged like the periscope of a submarine to protect the observer.

SPOTTING THE SHOTS

In the great war just brought to a close the airplane has proved invaluable for locating the enemy and directing the fire of artillery. In the early days of the war the aviator rose to a prearranged height and, maintaining that altitude, flew in the supposed direction of the enemy. As a guide, strips of white cloth were laid on the ground, serving not only to indicate direction and the position of the battery but also for sending certain instructions. After the airman had located his target, he sailed right over it and signaled to his battery by dropping a Very light—something very much like a Roman candle—using one or a

© *Kadel and Herbert.*

Belgian Anti-Aircraft Gun

Showing the arrangement on side of wheel through which gunner sights on enemy airplanes.

number grouped in some prearranged combination. Two observers near the guns with instruments between them checked off the distance automatically, which they could do with considerable accuracy since the airplane's height was known. The firing could then begin. The direction or line of firing was checked by the airman, who steered in an elongated oval between the batteries and the enemy, signaling with Very lights. Similarly, he reported how the shells were bursting, whether short or beyond the target, or whether they were landing true.

As the war progressed airplane artillery observation became more and more perfect. Instead of the crude means already alluded to, the airplanes were equipped with wireless telegraph transmitters for signaling back to the battery. In this manner it was possible for the airman to observe the fall of the shots, and to signal back any necessary corrections. Then, too, range-finding was done largely by photography. The airplane flew over the enemy position and made photographs. These various photographs were then assembled into a composite photograph or mosaic map, indicating not only the territory held by the enemy, but also No Man's Land and the airman's own side of the line. By means of this mosaic map, it became possible to determine ranges to a great degree of accuracy, because the scale could soon be determined by noting the distance between familiar objects behind one's own line. Again, in some instances the altitude at which the photographs were made was known, so that the scale of the map could be determined to a nicety.

Mosaic maps of this kind have in a large degree accounted for the marvelous accuracy of the artillery of both sides. Such maps have been ruled off into squares, each designated by a number or position, so that the aviator, with a duplicate map, could signal his battery which square to aim for in the first place, and then correct the shots until they registered exactly on the target.

Observation balloons have also been responsible for the accuracy of artillery. The observer, provided with a map divided into squares, was in a position to signal by telephone to his battery what square required attention, and what kind of attention was best. Thus he signaled down to fire at square so-and-so, using high explosive or shrapnel or even gas. In that manner the enemy could hardly move within view of a kite balloon without bringing down upon himself a torrent of shells.

AIMING BY EAR

The Sound-Ranging Devices Employed to Locate Hostile Guns, Planes and Submarines

IN the preceding chapter it was shown how the problem of hitting the enemy is solved when you can see him. But the World War developed an extraordinary variety of situations where you can't see him, or where you can see a number of places any one of which might be the one in which you are interested. A submerged submarine represents the first case, a hostile gun which is doing a great deal of damage from a concealed emplacement is a fair sample of the second. Now we can hardly submit to the damage inflicted by a "sub" or a gun just because we can't find the "sub" or the gun visually; we have got to find it in some other way and put it out of action. But how? To this question the caption of this chapter reveals the answer, as developed by the war.

It may be taken as a maxim of modern warfare that, wherever the enemy is and whatever he is doing, he will make a noise in doing it. If he is firing a big gun at us from fairly near by, or if he is flying over our heads on a dark night with a cargo of bombs, we will hear him with our unaided ears; if he is farther away or engaged in a comparatively silent activity like submarining, we may need to use artifice to bring him above the threshold of

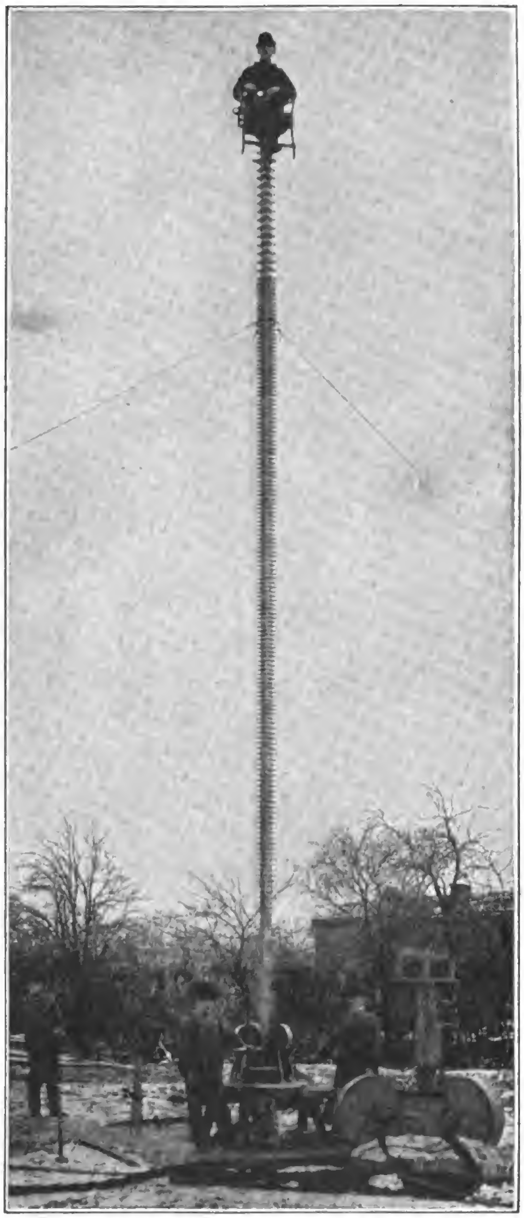
audibility. But in any event, whatever the circumstances, rest assured that we can hear him.

In the effort to take advantage of this situation both parties to the late conflict exerted their ingenuity early and late to develop apparatus and to improve methods of sound-ranging, on land and in the air and at sea. The first place where the art of locating the foe by listening to him was brought to a fair state of perfection, was in searching for distant and concealed batteries. Without developing any elaborate apparatus, a little ingenuity in the practical application of a very simple mathematical principle made it possible to locate concealed guns with a very decent degree of accuracy. Since the principle involved is more or less general to all sound-ranging, it may be worth while to look into it with some fullness.

A PROBLEM IN GEOMETRY FROM THE FRONT

Suppose we have two observers stationed at A and at B, 4,000 feet apart, and connected by telephone. Let them be provided with electrical apparatus and connections whereby both can record, on a single clock dial, the precise moment when they hear a given gun. This means that they can ascertain the precise time that elapses between the receipt of the sound at their respective stations. Suppose that it were thus established that observer A hears the report two seconds before observer B. Since sound-waves travel some 1,150 feet per second, this means that the gun is 2,300 feet nearer to A than to B. If the barometer is unusually high or unusually low, the sound velocity will be increased or decreased owing to the changed density of the air; but this is a known factor and can be taken into account.

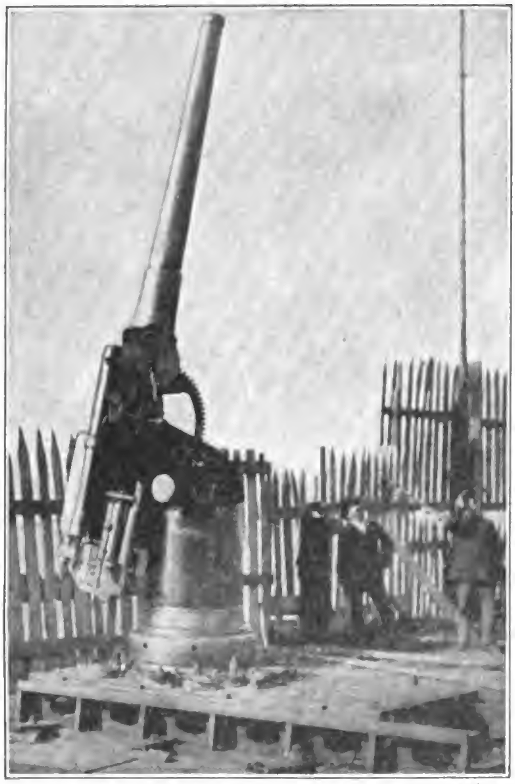
If the mathematician were now called in, he would point out that the conditions determine a hyperbola, and that the gun is located somewhere on this curve. For the hyperbola is defined as the locus of points whose distances from two fixed points differ by a fixed amount. Moreover, if we are given these fixed points and this fixed difference, the hyperbola is completely determined, and can be drawn. The mathematician would prefer to say that its equation is determined, but the artillerist goes right ahead and draws the curve, without bothering about the equation.



An Observation Tower that Goes with the Soldiers

Long before the war the Germans worked out an interesting and ingenious system of observation towers of the type shown in this illustration. Normally, the tower is collapsed as shown at the right, but by turning a pair of handles it can be fully extended to forty feet or more.

With A as center, he draws a series of circles a_1, a_2, a_3, etc., with any convenient radii —say 1,000, 1,250, 1,500, . . . feet. Then about B he draws another set of circles b_1, b_2, b_3, etc.; only this time he takes each radius 2,300 feet greater than the corresponding radius of the first set. Each circle of the first



Courtesy of Scientific American.

Guns Which Shoot into the Sky

No branch of artillery received more attention than the anti-aircraft. In the beginning the range was only a few thousand feet, but toward the end guns were available for ranges up to 15,000 feet, or about as high as most airplanes ever flew. The gun here shown is an Italian anti-aircraft gun.

set then intersects the corresponding circle of the second set in a point that is 2,300 feet nearer to A than it is to B. All of these points are on the hyperbola; any one of them might be the location of the gun sought. When all of them are joined by a smooth curve, that curve is the hyperbola, and the gun lies somewhere on it.

Using the same method to determine the time-difference between the receipt of the sound at A and at a third station C, a third set of circles can be drawn about C, with appropriate radii. If the report reaches C one second after it reaches A, for instance, the circles c_1, c_2, c_3 . . . will have radii 1,150 feet greater than the corresponding radii of the circles about A. The intersections of the circles about A with those about C give us a second hyperbola, upon which also the gun lies. But if it lies upon both hyperbolas it lies at their intersection; so that when both curves have been drawn, its position is fixed.

FINDING THE HOSTILE GUN

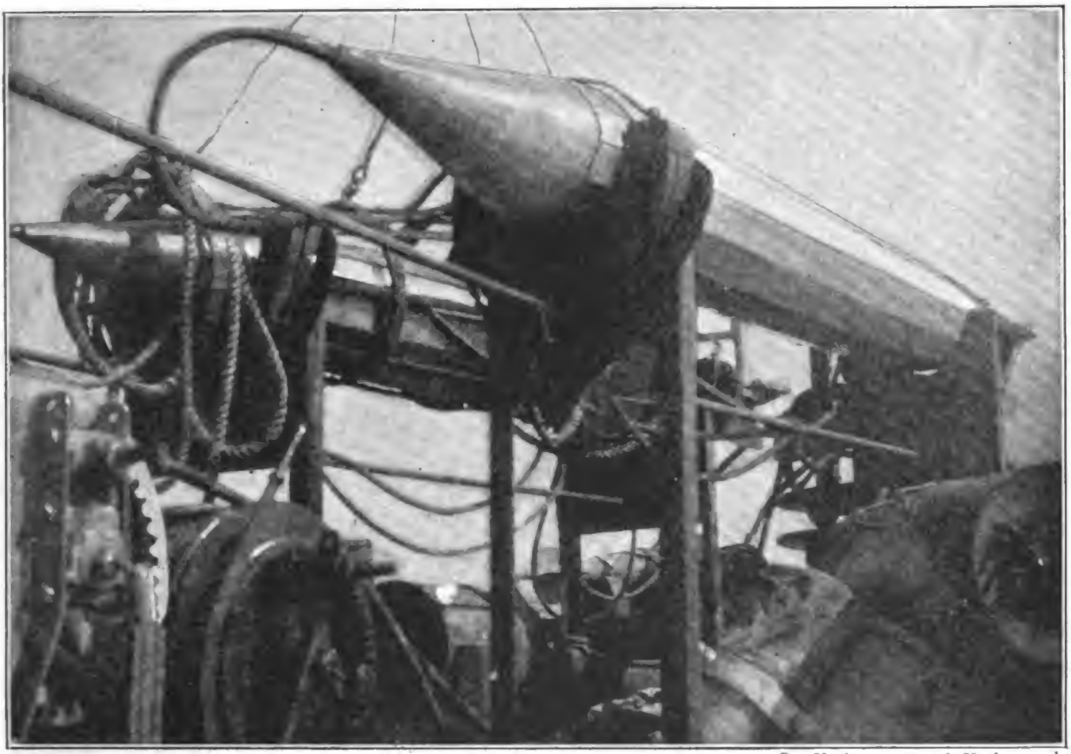
It will be observed that in theory the method is the simplest; but naturally there arise various difficulties in practical work. Apparatus must be of strong make-up, but sufficiently sensitive to secure accurate timing. Then a given sound must be distinguished with certainty out of many others, and the report of the detonation must be kept distinct from the sound of the shell flight. Allowance has also to be made for the effect of wind velocity upon the travel of sound, and for other factors. But in spite of all this the method was reduced to successful practice at a comparatively early date—the more so because of the possibility of averaging a number of trials for the time-difference, and again averaging a number of indicated positions as obtained from various combinations of listening posts.

The method was found especially useful for locating batteries that had been successfully camouflaged. Against this the enemy uses various artifices to hinder accurate work. For instance, he fires at a carefully worked out distance other cannon which produce false detonations; or he fires at exactly the same instant a number of guns at various ranges. While it is possible partly to meet these and other hindrances, it is not easy to do so, and it is not possible to checkmate them altogether. On the whole, the margin of error which they introduce into the work is an uncomfortable one; and the electric detector was born in the effort to reduce it.

In turning to this, the sound-rangers were hardly treading untrod ground. Always there had been circumstances under which the distance of a hostile outfit might be too great to

permit satisfactory returns by the unaided ear; or the enemy may be operating in something, like an airplane or a submarine, that merely makes a noise as distinguished from a report. Under such circumstances it is necessary to have apparatus for receiving the sound, and perhaps for magnifying it as well. And it is immediately found that when any extended mechanical equipment is necessary for its reception, the matter can be simplified by incorporating a device that will automatically indicate with accuracy at least the direction, if not the distance.

The one place of all places where this sort of thing is practically forced is in anti-submarine work. Much reliance was placed, during one period of the war, upon the use of airplanes in the detection of submarines. The fact is, however, that when the U-boat submerges to a depth of 15 yards its whitish trail is invisible from above, and we must fall back upon some other way of locating it; and this means we must seek some way of employing in the work of detection the sound waves propagated by the screws and auxiliary machinery of the submarines. But it must be remembered that while these waves travel through water with a speed four times that which they exhibit in air, there is no possibility of perceiving them directly by ear. It is necessary to have recourse to an instrument which can pick the waves out of the water and transmit them to a listener lodged in a habitable medium.



© Underwood and Underwood.

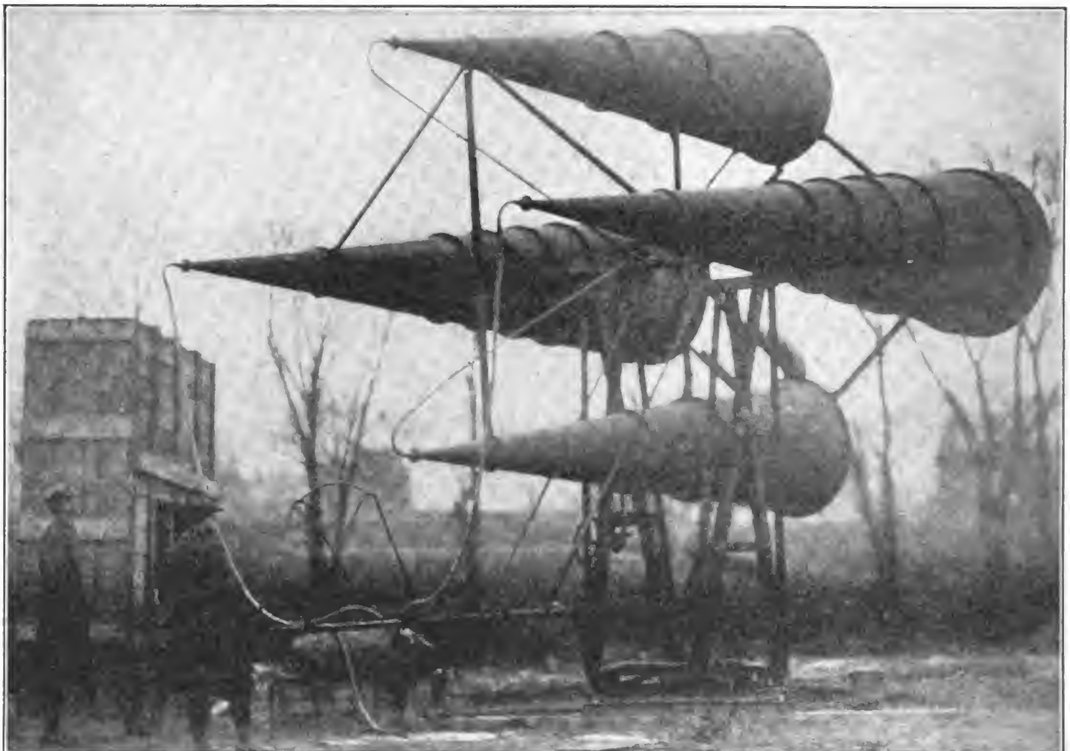
The Hydrophone

A device which was used to detect the presence of submarines.

Several such devices existed before the war, and in addition a quantity of inventions of one sort or another have seen the light of day since. The general principle on which these "hydrophones" work is that sound is loudest when it falls perpendicularly upon a membrane or diaphragm. This may be verified by any one who has access to a telephone. Get somebody to speak into the instrument from a distance of a yard—first directly in front of it, then diagonally off to one side. The sound will be heard far more distinctly

and far louder in the first case than in the second. And if we translate this into terms of sound-ranging, it means that if we turn a sound-receiving instrument of any sort about until a given sound has a maximum loudness in it, the source of that sound is located on a line perpendicular to the receiving surface. If we do this twice, at two different points, the source is at the intersection of the two perpendiculars, and is to be located by solving a simple exercise in trigonometry.

The hitch in this method lies, not where the layman might suppose, in any difficulty in reconstructing accurately the triangle having the two receivers and the sound-source at its vertices. When we reflect that a base-line a couple of feet long is sufficient for the visual ranging of objects up to several miles away, and that a base-line of 186 million miles, across the earth's orbit, was ample to measure the distance of Alpha Centauri, more than fifty million million miles away, the base-line for sound-ranging between two receivers in the same room does not seem quite so insignificant after all. But the trouble comes when we attempt to say when the loudest sound is heard. We are almost certain not to settle finally upon the exact position of the receiving surface for which the sound has a true maximum; and of course this has a serious effect upon the accuracy of the apparatus. A great many American inventors attempted to take the sting out of the submarine along these lines but it was left to a Frenchman to succeed in the effort to devise a really workable hydrophone for this purpose. His solution of the problem was a highly ingenious one, depending upon a very simple principle of physics, yet one which it had occurred to no one to utilize.



© Press Illustrating Service.

Long Horn Anti-Aircraft Set

Used to locate enemy airplanes.

THE SOUND LENS AND THE HYDROPHONE

The fundamental fact upon which Lieutenant Walser built is that sound, like light, is

refracted on passing from one medium into another. We are accustomed to diagrams which assume that the complex of light from a given object consists of a number of component waves, which may be taken to be parallel if their source is sufficiently remote, which remain parallel so long as no obstruction is interposed in their path, and which are bent as soon as they are called upon to enter a medium of different density from that in which they were propagated. And it is just so with sound waves.

Walser therefore interposed in the path of sound waves a sort of acoustic lens. Just as in the case of light, this causes the individual waves that make up the sound complex from a given source to come to a focus, with the double effect of strengthening them and sorting them out from the sounds that proceed from other sources. Indeed, just as light from various distances is brought to focus at different depths, so several sources of sound give rise to as many foci, of which the geometric locus can be calculated. Then from the position occupied by the focus that pertains to any particular source of sound, the position—or at least the direction—of that source can be calculated.

Once this general idea had been formulated, it remained for the lieutenant to work out the practical details. As finally adopted and used with huge success in the detection of submarines, the acoustic lens was in the form of a spherical segment set into the side of the chaser or destroyer. In the bulging surface of this were a series of circular holes, each filled with a sensitive vibrating plate. The effect is to focus all sounds received; and the focal points all lie on a circle, whose position and size, of course, depend upon the radius of the lens segment and upon other elements which can be controlled. There are two of these lenses on each vessel, one to port and one to starboard. The two give upon a single cabin, well insulated against sounds other than those that enter through the lenses. The observer is seated here, with a listening helmet to which are attached two ear-trumpets, one for each lens. The trumpets are mounted on a rotating mechanism, so adjusted that as the operator turns a crank the trumpets revolve about the respective focal circles.

In using the apparatus, the operator can manage to hear a given sound, not only when the trumpet is precisely centered at the focal point for that sound, but when it is anywhere in the neighborhood of that point. He hears it loud and clear, however, only when the axis of the trumpet passes through the focus, so that the trumpet is centered at the focus. It is the same thing as looking through a lens. Under ordinary circumstances it would be difficult or impossible to select a point from which a given object is seen with absolute maximum effect. But when you look through a lens, while you get some notion of all parts of the field from all points, no part is truly clear except at its focus; so there is no possibility of mistake as to where a given object is best seen. It is just so with the sound focus.

Courtesy of Scientific American.

Under Side of Vessel

Showing the latest type of hydrophone.

The operator explores the field by keeping the trumpet continually in motion. He locates every suspicious sound by carefully bringing the trumpet to the position where that sound is loud and clear. The instrument has been previously calibrated, so that when he succeeds in getting the maximum intensity for a given sound, he reads off the direction of its origin on the scale that runs around the edge of the rotating drum. Distance is then estimated by taking account of the intensity of the sound; and of course, as the vessel sets off in pursuit of the source of the sound, the operator of the hydrophone keeps it in focus. It is thereby possible to steer a straight course for the cause of the disturbance.

OTHER THINGS TO LISTEN FOR

A somewhat different idea is embodied in a good many instruments, devised some for land use and others for the same purpose which the apparatus just described fulfilled so successfully. While it may be extremely hard to tell when a sound is at an exact maximum, it is comparatively easy, especially with the aid of electric recorders, to tell when two sounds are of equal intensity. So first and last, there were a good many designers who got out some form of sound detector involving two receiving surfaces, joined so that they could be moved with reference to one another. The idea was to try various positions of the two membranes, until the suspicious sound made an equal impression upon both; and then the source would be found at a point equidistant from the two.

In some cases—notably in defense against aircraft—the sound detection service is called upon, not so much to locate the enemy, as to tell when he is abroad. In the brief interval that elapses between the moment when the unaided ear can hear an approaching plane and the plane's arrival, there is not enough time for the reception committee to get prepared. So the French, as the most interested parties, got up a number of horn outfits which were capable of picking up the sound of an approaching plane long before it was audible to the human ear. Even more interesting than this development, however, is one which the Americans brought out for the same purpose, consisting of a parabolic sound mirror. The student of optics will tell us categorically that the greatest efficiency is to be got out of a parabolic mirror; so the acoustic engineer was following a pretty well marked path when he built his sound detector in that form. This outfit was able to pick up a hostile plane at a distance three and a half times as great as the extreme range of the unaided ear; in addition, it was extremely light and so portable to the last degree.

THE PHONOTELEMETER

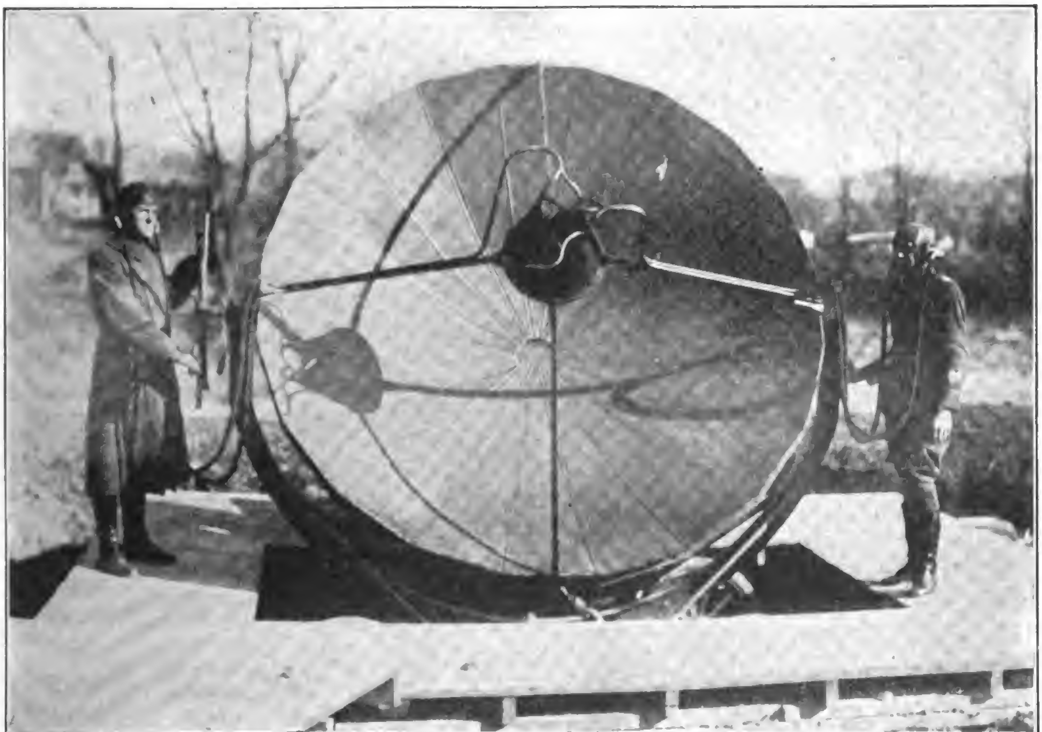
Given such efficient aids to the location of the enemy as these, it was but a step further to the utilization in the field of the valuable sound-detection powers of electricity. One of the most effective instruments of the entire sound-ranging campaign was the phonotelemeter, another American development. In this apparatus the dual reception principle is again employed; only here the two points of impact for the sound are so close together that without the electrical features of the device, no distinction could be made between the moments at which the sound reaches them. But the assembly includes a tuning fork which is kept in motion electrically; and its successive strokes divide a second so accurately into so many parts that it is a simple matter indeed to secure a graphic record that combines the strokes of the fork and the impact of the sound upon the two diaphragms, and accordingly shows just how many thousandths of a second elapsed between the two impacts. And this makes it a matter of comparative ease to get up an instrument which will reveal in a moment the precise distance and direction of any source of atmospheric disturbances. Indeed, the phonotelemeter is credited with having spotted 117 hostile guns or batteries within a period of 24 hours—all on the five-mile front which is covered by a single instrument.

SOME THINGS THAT CAN'T BE DONE

The technique of sound-ranging is a vast improvement over older methods of locating hostile points of fire, mainly because it does not require such extensive data. This necessity for sufficient data is quite generally over-

looked in reports that get printed in supposedly reliable organs. Thus, all the daily papers carried, in the spring of 1918, a tale to the effect that the big German gun that bombarded Paris had been located in the St. Gobain Forest by reconstruction of the trajectory when the shell passed through a double awning. The holes, it was gravely stated, were perfectly clean-cut; they were measured with excruciating care and the exact direction of angle of fall, and the process outlined in the story could then have been carried out with more or less accuracy, after a guess had been made as to the weight of the shell. But in the absence of data as to remaining velocity, of course, nothing of the sort was possible.

The yarn is, in fact, a familiar one. The first time we heard it, it was got up in a form calculated to extol the wonderful ability of the Yankee. An American artillery officer



© Press Illustrating Service.

An American Paraboloid Sound-Mirror

Which was used to detect the presence of enemy airplanes at night.

their line of centers was found; and from this "the French artillerists were able to follow back the course of the shell to the mouth of the cannon."

With all due respect to the gentlemen who accepted this yarn, it is of course an absurd one. If the French authorities had had advance notice of the fact that one of the German shells was to pierce this particular awning, and had there set up the usual electric device to time its flight through the space between the two members, the striking velocity would have been known as well as the

was reported as having been traveling along a camouflaged road, when a shell pierced the burlap roof above him and struck at his feet with a thud and an explosion. Notwithstanding that the shell's refusal to turn out a dud prevented the worthy gentleman from even recognizing its caliber and thence its initial velocity, he at once estimated its angle of fall from a glance at the hole it had torn in the camouflage, performed a few mysterious calculations—whether in his head or on his cuff was not specified—and telephoned the location of the offending piece to the nearest bat-

tery, which promptly blew it off the map as a rebuke for its presumption in disturbing the colonel's reveries.

Naturally, this whole tale is even more ridiculous than that from Paris. If an invisible gun is to be located promptly and accurately, sound-ranging will have to be used. This is the only method that makes it unnecessary to know anything about the gun itself —its caliber, for instance.

THE RÔLE OF FIELD ARTILLERY

What Comprises Field Artillery, and What We Possessed in the Way of Guns Prior to Our Entrance Into the War

IT is not going too far to say that the growth in power and numbers of field artillery and its dominating influence on the field of battle was one of the most striking developments of the European War. Prior to the war field artillery consisted of direct-fire guns of the 3-inch to 4-inch caliber and high-angle fire guns or howitzers, which ran from 4.7 inches to 7 inches caliber in our own army, with a few pieces of larger caliber, say 8 to 9.5 inches, in the European armies.

Germany and Austria, having in view the destruction of the steel and concrete fortifications of the nations which they were preparing to attack, set themselves to develop new artillery of such enormous destructive power that it would have the fortifications completely at its mercy. As the result of extensive experiments carried out at their various proving grounds, the German and Austrian authorities developed certain mobile howitzers of unprecedented size and power, capable, where the roads were favorable, of transportation with the armies, and of being quickly brought into action, either upon the carriages on which they were transported or upon hastily prepared foundations of concrete. Best known of these great pieces are the Skoda 12-inch Austrian howitzer and the German 11.2-inch and 16.5-inch howitzers. How these guns quickly reduced the fortifications of Liège, Namur and Maubeuge is now an old story familiar to every student of the war.

THE VALUE OF BIG GUNS

When the contending armies on the various fronts had settled down to trench warfare and reliance had come to be placed upon earth fortifications, it was found that these heavy pieces, together with the lighter howitzers of from 6- to 9.5-inch caliber, were equally efficient for tearing the trenches and the various forms of field earthworks to pieces and opening the way for infantry assault. The smashing and leveling effect of the big howitzers has been well illustrated in the assault on Verdun, and in the great offensive of the Allies at the River Somme. Thus it has come about that there has been a great increase in the types of new guns and it is now certain that the big howitzers of from 9.5 inches to 12 inches caliber and over have come to stay.

The field artillery of the United States Army (until the time we entered the war) consisted of seven or eight types of gun. First the guns of minor caliber, namely, the standard 3-inch field-gun, the older 3.2-inch field-gun, and the 2.95-inch mountain gun; the guns of mid caliber, including the 4.7-inch direct-fire gun, the 5-inch siege gun, the 4.7-inch howitzer and the 7-inch howitzer, this last named being an early type and now considered obsolete; of the major caliber guns of from 8 inches to 16.5 inches caliber our army did not possess one.

The complete field gun consists of two parts —the gun and its limber or caisson, the latter containing the ammunition. Each part is mounted on a pair of wheels and when the gun is in battery the gun and its limber are placed side by side, the caisson abreast of and to the left hand side of the gun. The rapidity of fire of the field gun is due to the method (first adopted in the Navy) of mounting the gun in a sleeve in which it recoils and placing

the telescopic gun-sights on the carriage, where they remain stationary during the recoil. This makes it possible for the gun to be maintained continually on the target. The gun-pointer keeps his eye on a panoramic telescope. It is his duty to maintain the gun at the correct elevation by means of an elevating hand wheel. The latest field pieces are provided with a traversing mechanism which allows the gun to be traversed to a limited number of degrees independently of any movement of the gun carriage. The carriage is prevented from recoiling by means of a spade at the end of the trail, the spade being driven firmly into the ground. The recoil of the gun is taken up and controlled by means of a cylinder, filled with oil and water. During the recoil, the movement of the gun compresses a coiled spring which serves to bring the gun back into battery.

The operation of these 3-inch field pieces is very rapid; and it is claimed that, under favorable conditions, the French 75 centimeter (approximately 3-inch) gun has fired as many as 20 rounds in a minute. Our 3-inch field piece fires three kinds of shell, each of which weighs 15 pounds. They include a common steel shell containing 13 ounces of explosives; a common shrapnel shell filled with 252 balls, the interstices being filled with a smoke-producing matrix; and a high-explosive shrapnel in which the interstices around the 285 balls are filled with a matrix of high explosive. In the case of the shrapnel, the bursting charge of loose black powder is carried in the base and the time fuse at the nose of the shell. The fuse is so set with reference to the range and the time of flight, that the black powder will be ignited and the balls driven from the case just above the body of troops to be attacked, the balls scattering and falling in a cone-shaped mass upon the enemy. The balls are shot out of the case with an added velocity of from 250 to 300 feet per second. The high-explosive shrapnel will eventually replace all types of shell for the 3-inch field gun. The maximum range of this gun on a level platform is about 8,000 yards with the gun at maximum elevation. If the trail be sunk in the ground the range is increased to about 9,500 yards. This gun is used entirely against personnel. The older 3.2-inch gun has an extreme range on a level platform of 4,500 yards.

An American 3-Inch Field Gun

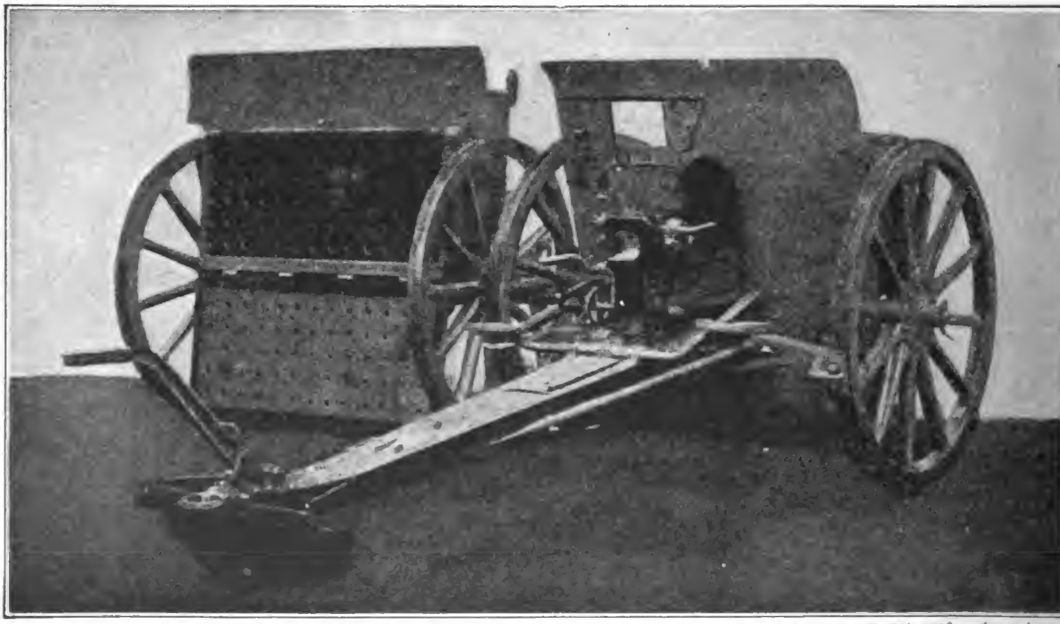
A GUN THAT IS CARRIED ON MULE BACK

The 2.95-incn mountain gun is designed to be carried on pack animals. It is so built as to be quickly dismounted from and assembled on its carriage. The gun, weighing only 236 pounds, is in one piece, its total length being only 3 feet. It fires a 12.5-pound or 18-pound projectile with 920 and 750 feet per second velocity, respectively.

The 4.7-inch gun, like the 3-inch, uses fixed ammunition, the shell and the powder charge being contained in a common case; and it fires either shrapnel or high-explosive common steel shell. The projectile weighs 50 pounds and the maximum range with an elevation of 15 inches is about 7,000 yards and the maximum with the trail sunk below level is 11,000 yards. This gun is used for breaching earthworks and also against personnel in the open. The 3-inch gun is our only absolutely first-class field-piece; the 4.7-inch gun would be a most excellent piece if it were provided with a better carriage. As it is, the amount of elevation on a level platform is limited; indeed the 3-inch gun, having 9 degrees more elevation, has a greater range than the much more powerful 4.7-inch gun. The latest model of 3-inch gun just prior to our entrance in the war bore the date 1905 and the 4.7-inch gun was the model of 1906.

Our pre-war 4.7-inch howitzer is a shorter gun of lower velocity designed for use against overhead cover, dugouts, and intrenched personnel. Upon a level platform it has a maximum range of something over 6,500 yards, and barely 10,000 yards with sunk trail.

The pre-war 6-inch howitzer is a more modern piece being of the model of 1908. Its weight is 1,925 pounds and it fires a 120-pound projectile with a muzzle velocity of 900 feet per second and a maximum range from a level platform of about 6,700 yards. The gun is built up of nickel steel and consists of a body and a breech hoop. It fires common steel shell and shrapnel. The carriage carries a cradle in which the howitzer is mounted. The recoil is controlled hydraulically, and when the howitzer recoils it carries with it the cylinder, the piston of which, being fastened to the cradle head, remains stationary. The 6-inch howitzer is intended for use against overhead cover, dugouts and intrenched troops.



Courtesy of Scientific American.

Belgian Field Gun "In Action"

This illustration shows the relative positions of the gun proper and the limber when in action.

WHAT WE HAD BEFORE WE ENTERED THE WAR

The largest pre-war field piece that we possess is the 7-inch siege howitzer, model of 1898 and 1890. Like the 5-inch gun, it is too old in design to render it serviceable under modern war conditions. The weight of the gun is 3,710 pounds, and it fires a 105-pound shell with a muzzle velocity of 1,100 feet per second. Its range when firing from a level platform is 7,000 yards. It was intended for breaking down overhead cover and reaching intrenched troops. But this 7-inch howitzer is considered by our Ordnance Authorities to be obsolete; in fact, Brigadier General William Crozier, Chief of Ordnance, ignoring the 7-inch piece, stated that the heaviest piece of field artillery which we had in our service was the 6-inch howitzer above described.

It was very evident to any one who had followed the development of artillery in the European War, that in this branch of the service, so far as our equipment is concerned, we were sadly deficient. Not only did we possess altogether too few of the types of gun above enumerated, but we were entirely without field artillery of the major calibers from 8 inches to 16.5 inches. The fault was due, primarily, to the parsimony of Congress. With a totally insufficient force, the Ordnance Bureau had been trying to find time and the expert men to get out a design for a howitzer of about 7.6-inch caliber and for another one of about 9.5-inch caliber. The 7.6-inch howitzer would fire a projectile weighing 240 pounds, which is twice the weight of the projectile fired by the 6-inch howitzer, the heaviest field piece we had when we declared war on Germany.

© International Film Service

Assembling a United States Mountain Gun

The 9.5-inch howitzer would fire a projectile weighing something like 400 pounds. It was originally intended to fire a projectile weighing 480 pounds, which is twice the weight of the projectile fired by the 7.6-inch howitzers. The Ordnance Bureau wished to go up by steps of 100 per cent. in the weight of each projectile; that is, the weight of the

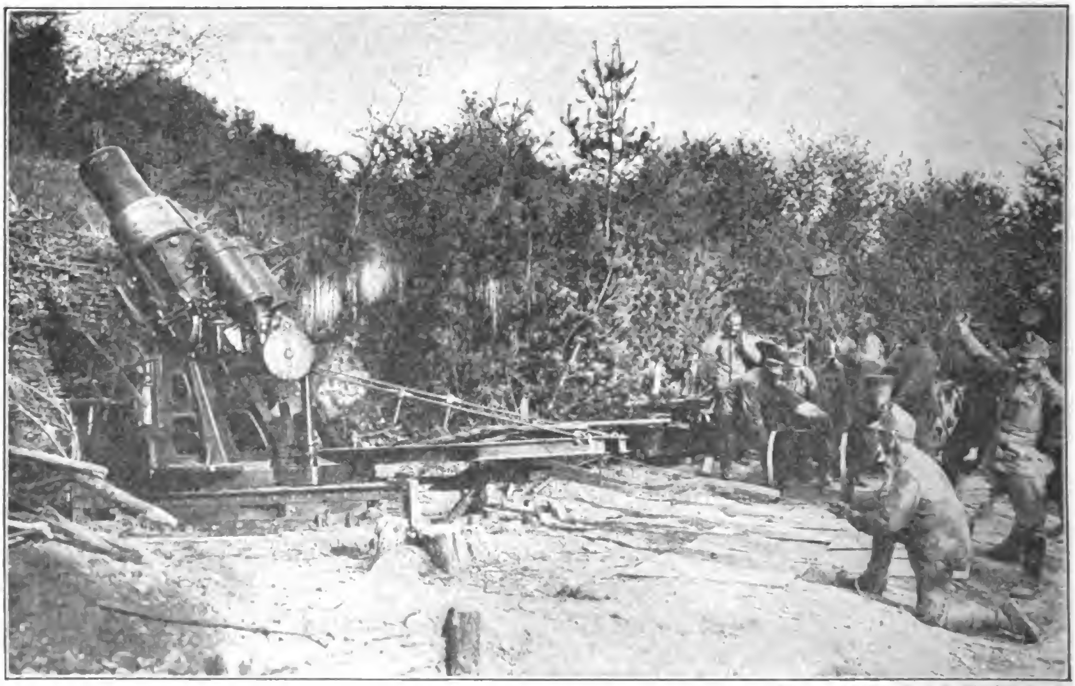
succeeding projectile was to be twice the weight of the projectile fired by guns of the next smaller size.

As a result of the increased importance given to artillery by the World War, and as soon as reliable information on the subject was available, our War Department appointed a Board known as the Treat Board, which made three important changes in the principles governing the supply of artillery. It increased the proportion of guns to troops from 3.6 per 1,000 of infantry and cavalry to 4.9 guns per 1,000. It increased the size of the largest pieces from a 6-inch howitzer to an 11-inch howitzer; and it increased the amount of ammunition supplied per gun from 1,800 rounds for the 3-inch field gun to 5,000 rounds. This increase is due to the enormous rate at which ammunition has been used up in the present war. General Crozier stated that he had heard reports coming directly from French officers to the effect that for a certain period of very intense action batteries of the 75 cm. gun had fired as much as 1,000 rounds per piece.

THE SHORT LIFE OF GUNS

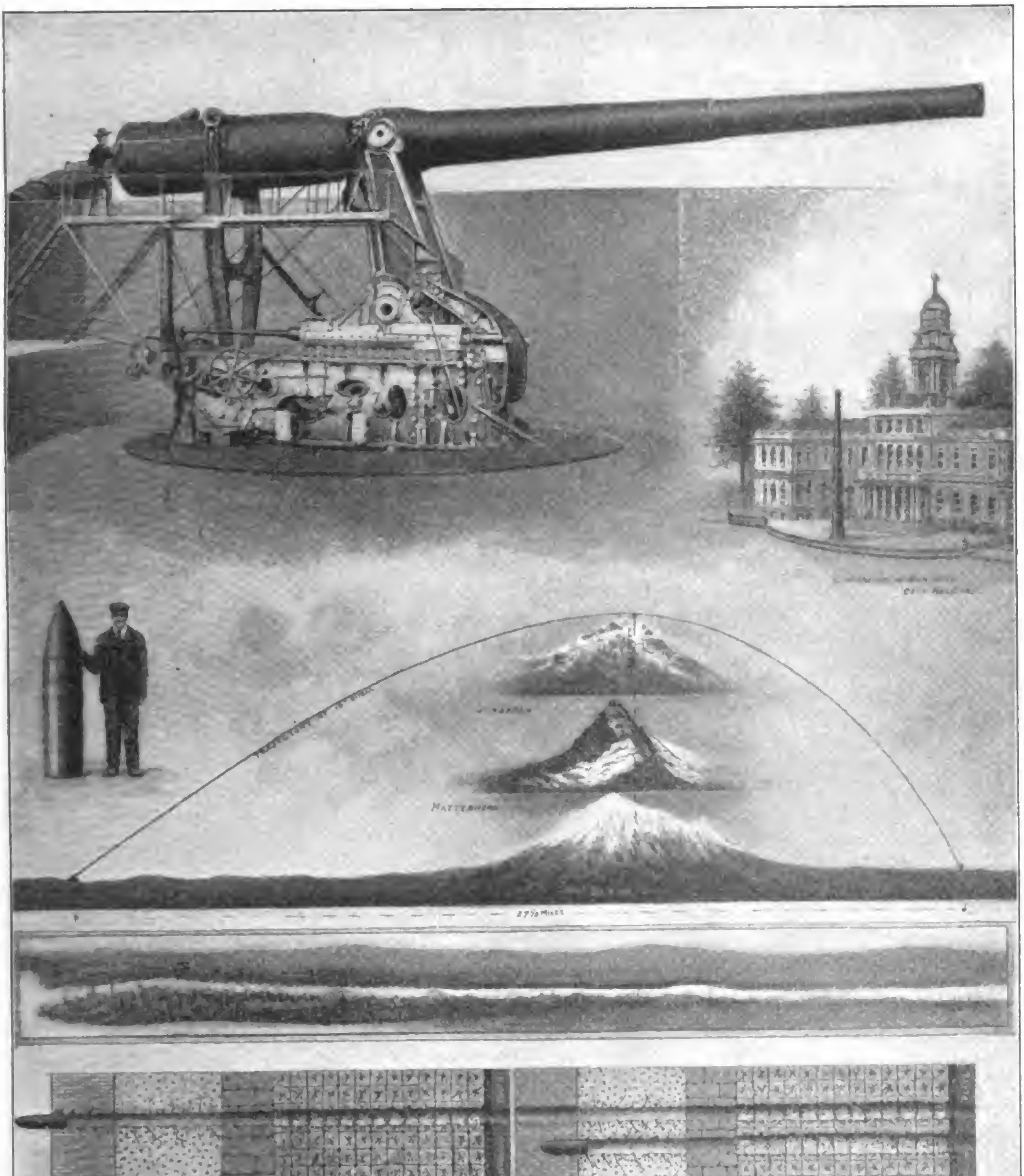
With regard to our supply of field guns, the General stated that we had at the opening of 1916 about 900 field guns of all calibers, and that we actually required 2,040 guns. Furthermore, the question of the number of guns now required is intimately bound up with the question of the life of the guns. There is an enormous wastage of guns due to erosion taking place in battle. The 3-inch field gun is good for between 2,500 and 3,000 rounds before its rifling becomes so worn cut that the gun becomes inadmissibly inaccurate. The larger field guns would last longer; say for 2,000 rounds at their very much slower rate of fire. In the big howitzers, which fire a much heavier projectile at lower velocity, because the heat of the propelling gases is much lower, there is very little erosion, and according to General Crozier they have "an almost indefinite life."

Now we referred above to the fact that in a single action the field guns may be called upon to fire at such rapidity that within a



© Underwood and Underwood.

An Austrian 30.5 cm. Siege Gun Which Was Used to Destroy Russian Forts



A United States Coast Defense Gun

The new sixteen-inch coast defense gun of the United States Army, together with its possibilities. The shell of this gun carries 27 1/3 miles and rises to a height of 44,100 feet. The penetrating power of the shell, as compared with the penetrating power of our former big guns, is shown below.

few days' time their rifling will be worn out and they will have to be sent back to the gun shops. Hence, not only did we need to increase the number of our field guns from 900 to over 2,000, but we had to provide a large reserve of such guns, and to provide ourselves with ample facilities for manufacturing a large number of new guns, and for relining the worn out guns during the progress of hostilities.

BIG GUNS AND WHAT THEY CAN DO

A Discussion of the Direct Fire and High-angle Fire Artillery Used by All Armies

IF a 1,046-pound shell is fired at Sandy Hook from a 12-inch coast-defence rifle elevated to about 11 degrees and charged with 280 pounds of powder, it will hit the side of a battleship distant 12,400 yards from the gun. If a shell weighing 825 pounds is fired from one of our 12-inch mortars elevated to an angle of about 45 degrees, and charged with 58 pounds of powder, the shell will land upon the deck of the same battleship at the same range of 12,400 yards. Because of its high velocity, the trajectory or line of flight of the shell from the rifle will be very flat, and it will take only about 20 seconds to arrive at the target. Because of the high elevation of the mortar and its low velocity of 1,325 feet a second, its shell will describe a parabolic curve of great height, and it will be in the air for over a minute of time. Because of its relatively high velocity and the relatively short time of flight, the 1,000-pound shell would reach the ship with a high remaining velocity and large penetrative energy; in fact, it would be capable at that range of penetrating a thickness of armor equal to the diameter of the shell, or say about 12 inches. The mortar shell, on the other hand, starting with a low velocity and subjected to the retarding effect of the atmosphere for over a minute of time, would reach the ship with a very low velocity, and therefore would be capable of only a limited amount of penetration; nevertheless, its energy would be sufficient to enable it to pass through the protective deck of a battleship and work havoc in its engine room or magazines. Each gun has its special rôle and its individual *modus operandi.*

WHEREIN DIRECT-FIRE AND HIGH-ANGLE ARTILLERY DIFFER

The high-velocity, direct-fire rifle is sighted directly upon its object; that is to say, the gun pointer maintains the cross wires of the gun telescope directly upon the ship; in other words, he sees what he is firing at. The gunners who elevate and traverse the mortars of our coast fortifications, on the other hand, never see their target. They are entirely hidden from the direct view of the enemy, and usually the mortars and the gun detachments are in deep pits sunk well below the level of the surrounding terrain. The data for the elevation and traversing (movement to right or left on a turntable) of the mortar are worked out by a group of officers who may be located in some protected position at a considerable distance from the gun.

Direct fire is used mainly for naval guns on board ship and for rifles in coast fortifications; but it is used to a limited extent in artillery work on land. Direct-fire guns are used mainly for attacking the armored portion of ships or the parapets of fortifications, or bodies of troops in the field—for any form of attack, in fact, in which the gunner can see directly on the target.

High-angle fire, on the contrary, is directed against the thinner horizontal armor employed on the roofs of the turrets, or on the one or more protective decks of a warship. In field operations it is used against the roofs of armored cupolas and the vertical protection of whatever kind which may be above the garrison. In field operations in the open, the 3-inch field pieces use direct fire where

© Scientific American.

A Huge Railway Gun

In the beginning, the Germans had more or less their own way in the matter of artillery. By 1916 the Allies began to come back at the Germans. During the Battle of the Somme huge British and French guns began to appear. These were mounted on railroad cars, so as to be readily portable, and of course carried a protective coating of camouflage.

it is possible, but because of the concealment, natural and artificial, of the troops in modern fighting, a large part of this attack must be aimed through information given by observers in positions on eminences or in airplanes or captive balloons.

Direct fire is used with high-velocity guns, elevated to not more than 15 degrees. Curved fire is used with howitzers of low velocity, elevated to not less than 15 degrees. High-angle fire is used with mortars of low velocity, elevated to not less than 45 degrees.

At the present writing it is established that the best armor-piercing shot fired from the most effective direct-fire gun is impotent on the present side armor at ranges consequent on the angles of elevation above 15 degrees. The velocity is so greatly reduced by the resistance of the air that the remaining momentum of the projectile merely serves to shatter it helplessly against the heavy side armor of the target. Direct fire has to-day a sure limitation of 15 degrees, and will have for some time to come. The limiting angle for indirect fire or mortar fire is likewise restricted, but from a very different cause.

Captured German Gun

This official photograph taken on the British Western front during the Cambrai offensive shows a British landship bringing in its prize, a 5.9 German naval gun.

THE LIMITATIONS OF MORTAR FIRE AND HOW THEY ARE OVERCOME

At angles above 65 degrees the time of flight becomes so great as to be prohibitive, and this marks the limit for the highest angle of mortar fire. There are other considerations involved in the strength of the carriage, and irregularities of flight above this angle, but these are subordinate to the unavoidable objection of excessive time of flight.

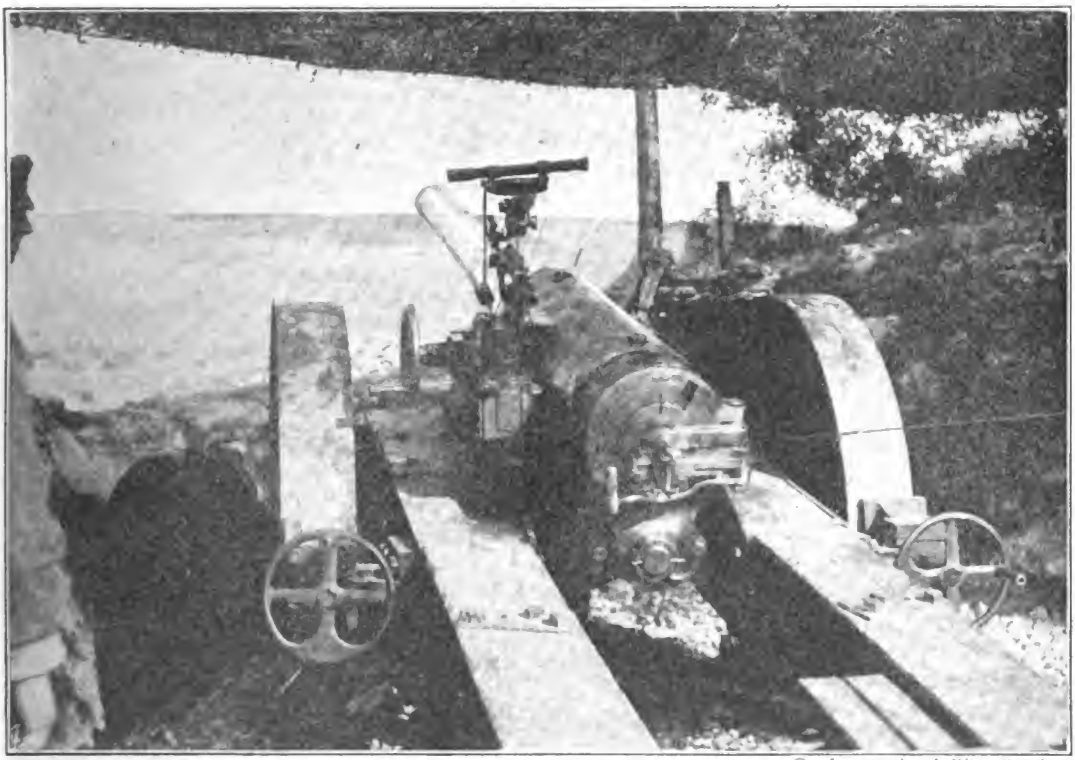
Of course, it is understood that to make a hit, it is essential that moving target and flying projectile arrive at the same spot at the same instant. In firing at a maneuvering battleship the element of time of flight thus becomes a most important factor, and it will be readily admitted that the time the projectile is in the air should not exceed one minute. By changing course and rate of speed, the commander of a maneuvering ship,

in such a long interval of time as this, can readily place her at other than the predicted or anticipated point where she is expected to be when the shot strikes. This limit points, at the outer range, to an angle of projection not exceeding 65 degrees, since at this angle it takes the projectile over a minute to perform its path of flight.

It is a peculiar coincidence that with limiting restrictions so widely divergent, the scope of angles of projection is about the same. The total change in elevation for direct fire is limited to 15 degrees, and that for mortar fire to 20 degrees. These limitations on the angle of fire thus prescribed place a great restriction on the attainable range. On this account it has been necessary to resort in mortar fire to what are called "zones." It is, of course, essential to cover every yard of range between the outermost and innermost limits of fire.

At a maximum velocity, within the power of the gun, behind a given projectile, the maximum range is attained at 45 degrees, but the minimum is not attained at 65 degrees. The only way to get less range after tnis angle is arrived at is either to reduce the powder charge or to increase the weight of the projectile, or both.

Since the longest ranges are of little value, on account of the inherent inaccuracies, it was decided in Uncle Sam's service to build a mortar only strong enough to carry the heaviest projectiles to moderate ranges. A comparatively light projectile was designed for the outermost zone. With this projectile a certain portion of the total zone is covered. The limits of this lighter projectile of 824 pounds weight are between a maximum of about 12,400 yards for 45 degrees, to a minimum of about 8,700 yards at 65 degrees elevation.



Heavy Artillery in Action

With the latest American mortars, of greater length and using a sharper nosed projectile, an extreme range of 19,000 yards has been reached. These mortars have been figured on for use at Panama against a possible attacking fleet.

CHANGING PROJECTILES AND POWDER CHARGES TO ALTER THE RANGE

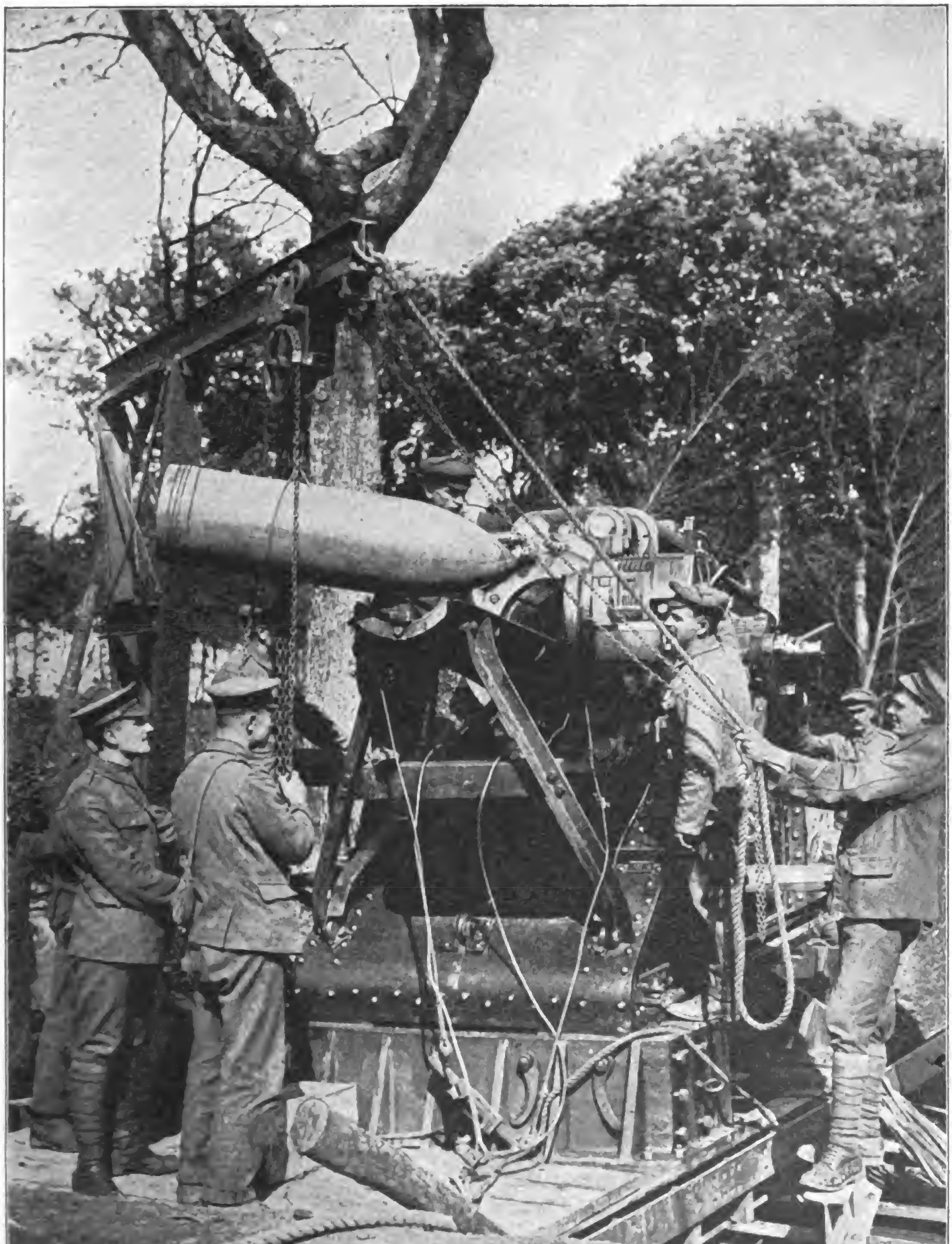
An approaching battleship is fired upon by mortars at the outermost range, and finally arrives at safe anchorage on account of the limiting angle of 65 degrees elevation, which results in the shortest possible range for the mortar under the restriction formerly adverted to. Alive to this situation, the mortar man employs a heavier projectile of 1,046 pounds weight, the same as that used in a 12-inch direct-fire gun, and so reduces his powder charge as to attain the same or but slightly greater range at his best angle of 45 degrees with this projectile than was previously attained at 65 degrees elevation with the lighter one. He thus establishes a second zone of fire that will last him till the enemy once more arrives at the angle of safe anchorage, as it may be called, of 65 degrees. Once again the powder charge is reduced, so that the angle of 45 degrees will result in range but little greater than was previously attained at 65 degrees. So on, by successive reductions of charge, the range is shortened with successive zones of fire till the minimum limit is reached.

The limiting range is for an angle of 65 degrees with the smallest powder charge that will result in stability of flight. Stability of flight means that in spite of the low velocity, the gyroscopic action of the elongated projectile shall still be sufficient to keep it steady in flight. The wobbling of a spinning top that is dying out is an illustration of the effect that a too low velocity might have on a projectile "tumbling" end over end.

To give the mortar crew time to change the powder charge from one zone to the next, a certain "overlap" of zones is provided. The next lower powder charge is so prescribed that at 45 degrees elevation the range will be somewhat greater than with the heavier charge at 65 degrees. To meet all these requirements, eight zones of fire are prescribed.

German 11-inch Howitzer

With such complications involved, and in connection with the fact that the mortar crew is hidden behind protecting parapets and does not even see the moving target attacked, results are marvelous. A mortar crew in test firings obtained seven hits in eight shots at a range approximately 10,000 yards, or nearly six miles. That all difficulties have been met and overcome, in the construction of a range table and adequate method of correction for normal conditions of atmosphere, wind, and travel of the target, that will give a mortar crew a fair chance of a hit, is an achievement in which the servants of Uncle Sam, who are



© *Scientific American.*

A Big British Howitzer in Action on the French Front

High-angle fire guns of this type were used in large numbers by the British, and proved particularly effective against the intrenched Germans.

responsible for this accomplishment, find a solid degree of satisfaction. In no foreign country has so great a success been attained by the methods of mortar fire.

FORT-SMASHING GUNS OF THE GERMANS

One of the most striking developments brought to light, or at least brought to public attention, at the beginning of the great World War was the enormous size and destructive power of the mobile artillery with which the contending armies, and particularly those of Germany, were equipped. The most formidable of these weapons were the enormous 11-inch siege mortars of the Germans which possessed an extraordinary degree of mobility in view of their weight.

The 11-inch mortar was developed and constructed in large numbers at the famous ordnance factory at Essen. In respect of size, weight and destructive power this piece marked the climax of a rapid development of heavy ordnance capable of being transported with an army and quickly emplaced for the reduction of permanent fortifications, such as Antwerp, Liège, and Namur. Up to the time of the Russo-Japanese War, a distinction was made between heavy and light siege units. The latter were mounted upon wheeled carriages and were capable of being moved with an army on the march. The heavier siege units, say of 9-inch to 11-inch caliber, required special means for their transportation. The massive parts, such as the gun and its carriage, had to be conveyed by standard gauge railway or by ship to some place adjacent to the field of operations, whence it was customary to lay a light military railroad or devise other special means for transporting the batteries to the locations assigned to them. Before the mortars could be erected and placed in working order, it was necessary to provide heavy masonry foundations, of sufficient area and mass to withstand the heavy shock of recoil. It can readily be understood that this preliminary work entailed the loss of much valuable time.

This was the method employed by the Japanese at Port Arthur in the reduction of that fortress. This enterprising people were the first to employ 11-inch siege guns for the reduction of permanent fortifications. They dismantled a number of their coast defense mortars in Japan; transported them by sea to the port of Dalny; laid a light military railroad from Dalny to the base at the hills encircling Port Arthur; built heavy concrete foundations, and erected upon them the mortars and their gun carriages. It was these siege guns which assisted in the sinking of the Russian ships in Port Arthur, and contributed very largely to the reduction of the forts which crowned the hills around the city.

The heaviest French siege gun at the beginning of the war was the 10.7-inch howitzer. This piece was tested during the maneuvers of 1907 in the "siege" of Langres. For field work or for transportation for the siege of fortifications it was horse-drawn, being carried in four parts on separate carriages, one carrying the gun, another the carriage, a third the slide, and the fourth the platform.

SOLVING THE PROBLEM OF TRANSPORTATION

The German 11-inch mortar marked a great stride in power and weight, and particularly in mobility, over any other mobile artillery constructed up to that time. The outstanding feature of this great mortar was that it was so mounted that the gun and its carriage could be hauled either by motors or by horsepower at a speed approximating that of the lighter siege artillery, and that when it reached the designated position it took but a short time to have the gun in battery, ready for the attack.

To describe this German gun briefly, it may be said that the barrel was made of steel, and consisted of the inner tube and the outer jacket, just as in practically all modern guns, and the total length of the gun was 11 feet. The breech was opened and closed by turning a handle through a horizontal arc of about 135 degrees; and a safety device operated by hand was provided to prevent premature firing or accidental opening of the breech. In spite of the fact that the breech mechanism weighed over 1,100 pounds, the construction was such that the opening and closing of it could be effected easily with one hand and in a few seconds' time.

The gun was transported on two separate vehicles, each of which was hauled by a single motor truck or a number of horses. During

transportation one unit consisted of the gun carriage, slide, recoil cylinders, trail, and permanent axle and wheels, the last named being fitted with broad flat feet popularly referred to as caterpillar wheels. The after-end of the trail during transportation was mounted upon a pair of wheels, thus making this unit a four-wheeled vehicle. The gun itself was transported upon a carriage upon which it was placed in such a position that the majority of the weight would fall upon a pair of caterpillar wheels.

To mount the gun when it had reached its assigned place, all that was necessary was to back up the section carrying the gun against the section constituting the mount, and then, by means of wire cables, draw the gun forward against the section into the sleeve and bolt the lug at the top of the gun near the breech to the piston rod of the recoil cylinder. The gun-transporting section was then drawn away, the trail lowered to the ground, and the gun was ready for firing.

The training gear gave a maximum elevation to the mortar of 65 degrees, and it worked upon a rapid system. The gun could also be traversed through an arc of 10 degrees horizontally, that is, five degrees on either side of the longitudinal center line of the carriage. The upper part of the cradle in which the gun barrel was made to slide carried a group of three cylinders. These cylinders comprised a standard form of recoil mechanism, wherein the central cylinder acts as a recoil brake, while that on either side is an air reservoir. The gun, as already stated,

Big French Gun on Western Front

This was one of France's most powerful types of artillery used to bombard the German lines. Note the camouflage along the barrel.

is connected, not to the brake cylinders, but to the piston rod; the brake cylinder remains stationary during the recoil, and it is the piston rod and the piston which move to the rear with the gun.

In the early days of the war it was soon established that the attack had far outstripped the defense. Thus fortresses on which vast sums had been spent and which were considered the last word in military defense, were soon reduced to a mass of crumpled and twisted ruins. Most fortresses of pre-war days were designed to ensure protection against high-velocity direct fire from big guns, and the high-angle fire from the lighter siege guns which were in vogue when these fortresses were designed. However, in the face of the huge mobile German siege guns, as well as a number of huge Austrian mortars which went to aid the Germans in Belgium, the fortresses were of no avail.

THE ALLIED ANSWER TO GERMAN ARTILLERY

As in so many other things, the Germans certainly had the advantage over the Allies in the matter of guns, particularly heavy guns. It was not before 1916, or during the great battle of the Somme, that the Allies were in some sort of position to dispute the artillery superiority of the Germans. Instead of mounting their heavy guns on caterpillar wheels, the Allies went to work and placed them on railroad cars, so that they could be quickly moved about from one part of the front to another.

The Germans got their first real taste of a powerful adversary in 1916. The French guns up to 400 millimeter, or 16-inch, and the British heavy guns then came into action. Indeed, it was these heavy guns that made possible the notable advances of the British and French troops, which forged ahead despite the powerful defenses of the Germans.

And the Allies did not stop at that. Month after month they kept adding to their artillery, until toward the end of the war they had more guns than they could really dispose of on the Western front, practically speaking. When America entered the fray the British and French placed field and heavy artillery at the disposal of our troops, who could not wait for the vast supply of artillery that was being designed and put into quantity production back home.

Our experience in the late war proved that, for a nation as unprepared as we were, but possessed of a large measure of initiative and adaptability, it is easier to provide the personnel than the material. Especially when we come to field artillery the task becomes most serious and the time element is the controlling factor.

Despite even our vast resources in raw materials, steel works, foundries, machine shops and skilled mechanics, to say nothing of a plentiful supply of capital, the problem required time for its full solution.

These facts were well known to our army officers, war college, general staff; and such of our leading generals as were willing, in their patriotic desire to arouse the country to the seriousness of our lack of artillery, to risk the wrath of the politicians, sounded the warning for many a year previous to the war.

However, the moment war was declared, the Army bent itself to its herculean task with its whole energy and our plans were laid upon a scale and prosecuted with a vigor which, if the war had run into another year, would have found our armies magnificently equipped. We had to begin work practically from the ground up; and, having at our disposal the accumulated experience of our allies during three years of war, our ordnance officers designed new models of all calibers and of every possible type which, when the armistice was signed, were already proving their high efficiency on the French front.

Perhaps the best measure of the work undertaken by the Ordnance Department of the Army, is the fact that up to September 30, 1917, contracts were issued amounting to $9,855,253,529.

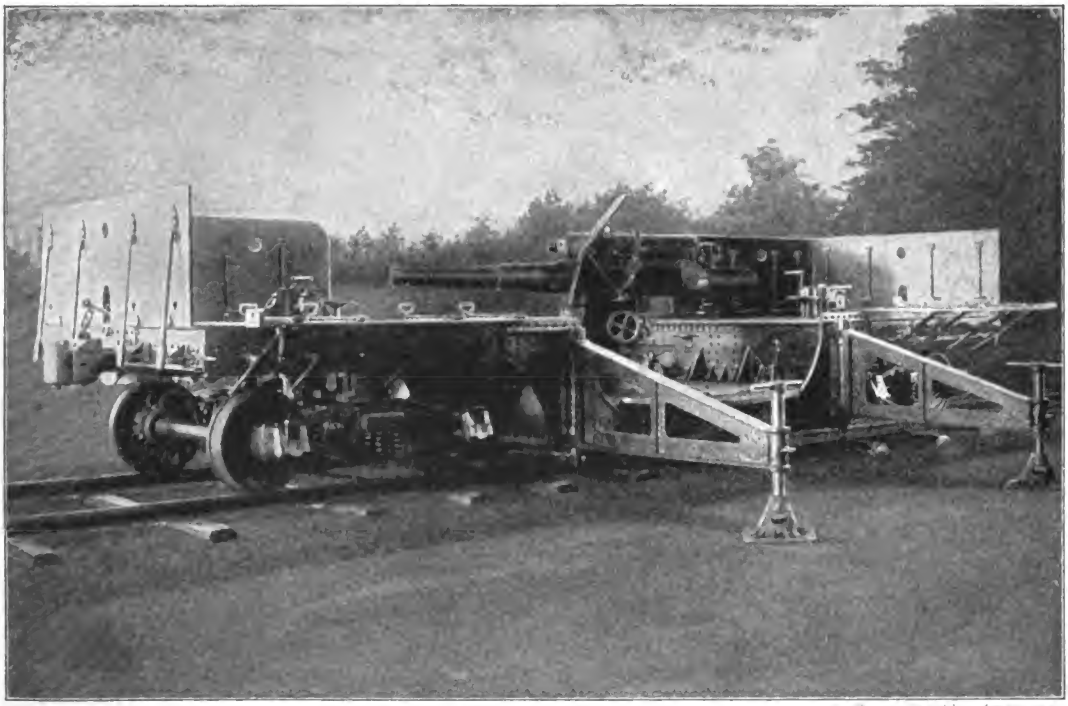
Naturally, the average citizen is attracted to size and power, and the huge, long-range guns of 12- and 14-inch caliber on massive railroad mounts, designed for the shelling of the back areas of the enemy country, far behind his front, receive most attention.

FOURTEEN-INCH RAILWAY MOUNT

First among these is the army 14-inch high-velocity gun on a railway mount. This mount was designed prior to the beginning

of the war. It was intended primarily for the mobile seacoast defense of this country, and, of course, was admirably adapted for service with our armies in France. Gun and cradle are mounted on a heavy, steel plate girder, the entire mount weighing about 250 tons. The gun is wire-wound, the caliber is 14 inches, and it is 47 feet in length. It fires a 1,200-pound projectile with 400 pounds of powder, with the high muzzle velocity of 2,900 feet per second. The range is about 19 miles. The recoil is partly absorbed by a hydraulic recoil brake, and the gun is returned to its initial position, or "battery," by counter-recoil springs.

The gun is placed in a firing position on a cast-steel bed plate, which is adapted to give the mount a traverse of 360 degrees. About five hours are required to place this mount in position, using a well-trained crew. The rate of fire is one round every two minutes; and the mount has the advantage of being adapted for use against moving targets such as battleships, as well as for use against stationary targets on land.



A 6-inch American Railway Gun

Railroad guns usually are arranged to be jacked up, as shown in this illustration, in order to take the shock of recoil off the wheels and tracks.

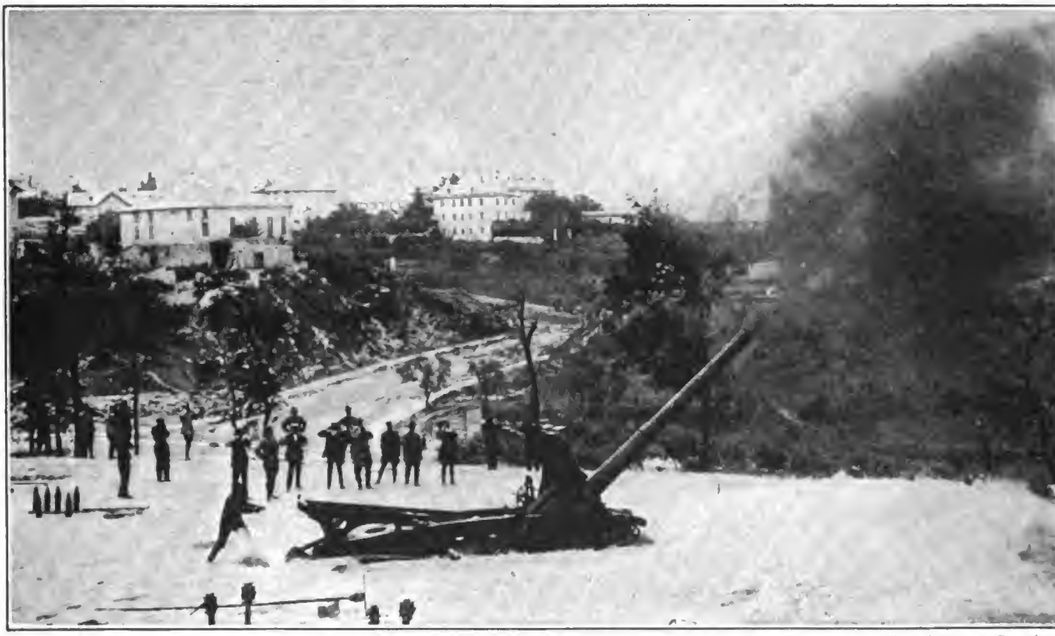
TWELVE-INCH SLIDING RAILWAY MOUNT

Another type among big guns is the 12-inch sliding railway mount. This has no recoil mechanism, the recoil being absorbed by friction produced by sliding the mount on the special track which supports it. It is operated on a curved track and is trained on the objective by moving the mount backward or forward. The entire mount is 105 feet long, weighs approximately 600,000 pounds and is carried on four trucks of eight wheels each. It has been moved on railway tracks at the rate of 40 miles an hour. This 12-inch gun is 50 feet long; it fires a 700-pound projectile, with a muzzle velocity of 3,200 feet per second (the highest velocity for a big shell of which we know), and with a range of approximately 28 miles. The mount was built by the Ordnance Department, with the exception

of the gun itself, in 85 days. After the track is laid and beam stringers placed, only about five minutes are required to move the mount into position and get it ready for firing, and it may be removed from the firing position in an equally short time.

SIXTEEN-INCH HOWITZER RAILWAY MOUNT

The long-range high-velocity guns above described are designed to attack the enemy's communications, railway depots, ammunition dumps, supply centers, etc., from 15 to 25 miles back of the fighting line. For the attack of the belt of country lying a few miles behind the front, and extending up to the front itself, use is made of howitzers, which fire their shells at a high angle of elevation, so that they may drop with a steep angle of descent, upon dugouts, concrete shelters, ammunition dumps, important cross-roads, and other vital elements in the enemy terrain. Conspicuous among these is our 16-inch howitzer, developed by the Ordnance Department, which is one of the most powerful howitzers known. It can be fired on its mount up to 45 degrees elevation, directly from the trucks, when resting on any standard gauge track. The energy of recoil is taken care of partly in the recoil mechanism and partly by permitting the car to move backwards along the track on its own wheels. After firing the mount is returned to its original position by means of a gasoline-driven winch, mounted on the forward truck, which hauls in a cable anchored to the track ahead. The extreme range is about thirteen miles. The total weight of the mount is 325,000 pounds and its length overall is 58 feet 4 inches. In spite of the weight of the gun of over 45 tons, it is so well balanced on its trunnions that it can be elevated to 65 degrees by one man in 40 seconds. The gun can be traversed 6 degrees to either side of center, so a total of 12 degrees can be secured. This is all that is required for range correction, and the direction is secured by moving the mount on a curved track. The



© *International Film Service.*

One of the Guns that Held Back the Austrians

As a result of the unfortunate defeat at Caporetto, the Italian army lost some 2,000 guns. Yet the Italian manufacturers had been making guns on their own account, and at the critical moment offered the government all the necessary guns to stem the Austrian onrush.

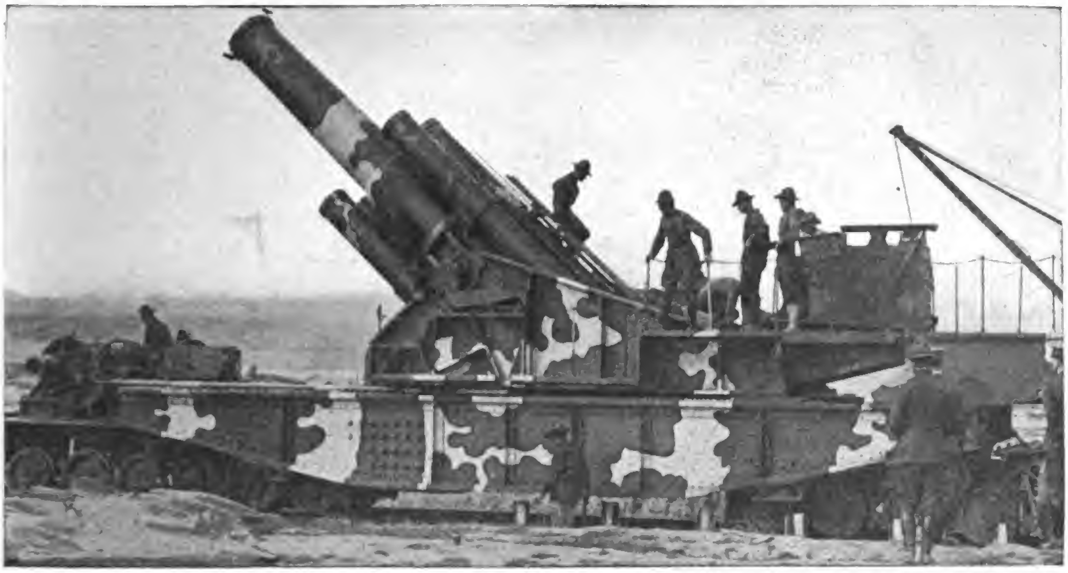
entire mount was built within 75 days after the order was placed.

TWELVE-INCH MORTAR RAILWAY MOUNT

The 12-inch mortar railway mount is designed to permit all-around fire and may be elevated from minus five to plus 65 degrees, having a range of nine miles at the latter elevation. The total weight of this mount is 177,000 pounds, the gun weighing 29,000 pounds, carriage 57,300 and car 90,000. The projectile weighs 700 pounds and the powder charge 65 pounds, which gives a muzzle velocity of 1,500 feet per second. This mortar is not designed for long-range but for plunging fire at shorter ranges, where great penetration is desired. The shells, filled with high explosives, are very effective in destroying ammunition dumps, dugouts, cement shelters, quarries, etc. When it is necessary to bring this mortar nearer the enemy, provision has been made to replace the standard six-wheel trucks by narrow gauge trucks, making the carriage very mobile and effective.

Upon firing, the mortar moves to the rear about thirty inches, the energy of the recoil being partly absorbed by the resistance which the fluid in the recoil cylinders on the bottom of the cradle offers to being forced past the pistons. A portion of this energy, sufficient to return the gun to its original position, is absorbed by compressing the air in the recuperator cylinder on top of the cradle. The return of the mortar is eased by buffers in the front of the recoil cylinders. Approximately 300 rounds have been fired from one of these 12-inch mortar railway mounts with no impairment of any of the working parts.

The guns above described are all adapted to transportation on railway trucks and in addition to those illustrated, mention should be made of a very effective 8-inch railroad mount, model 1918, with its own ammunition car, which at a maximum elevation of 42 degrees fires a 200-pound projectile to a range of 20,000 yards. This mount permits of an all-around fire without changing the position of the mount on the tracks.



The 16-inch Railway Mount Howitzer

EIGHT-INCH HOWITZER ON SELF-PROPELLED CATERPILLAR MOUNT

In addition to the above artillery, the Ordnance Department developed some mobile heavy artillery for transportation over the highways, and if need be, across the fields, quite independently of the highways. A very fine piece is the 8-inch howitzer mounted on a self-propelled carriage of the caterpillar

type, so designed as to make the entire unit self-contained and adapted for quick mobility. The self-propelled carriage is designed along the same general lines as the artillery tractors which played such a prominent part in the field operations of the Allied armies. It is propelled by a four-cylinder, heavy-duty, tractor motor developing about 75 horsepower at 850 revolutions per minute. The design of this unit is such as to permit a few degrees traverse of the howitzer to the right and left, as well as the full elevation of the piece. A small supply of ammunition can be carried on the platform of the gun mount, with a reserve carried on cargo-carrying "caterpillar" tractors, sufficient to serve the howitzer or battery of howitzers. This howitzer mount is capable of speeds ranging from about one to four and a half miles per hour, and is so designed as to require less than one minute to put it in firing position from road travel. The total weight of the vehicle is approximately 25 tons, though, on account of the large track area, the concentrated pressure per square inch is but slightly greater than that exerted by an ordinary horse. Sufficient fuel and oil are carried to permit the vehicle to travel about ten hours under full load, without replacing the supply.

The new ordnance includes, also, an 8-inch railway mount, with ammunition car; shell, 200 pounds; range, 20,000 yards.

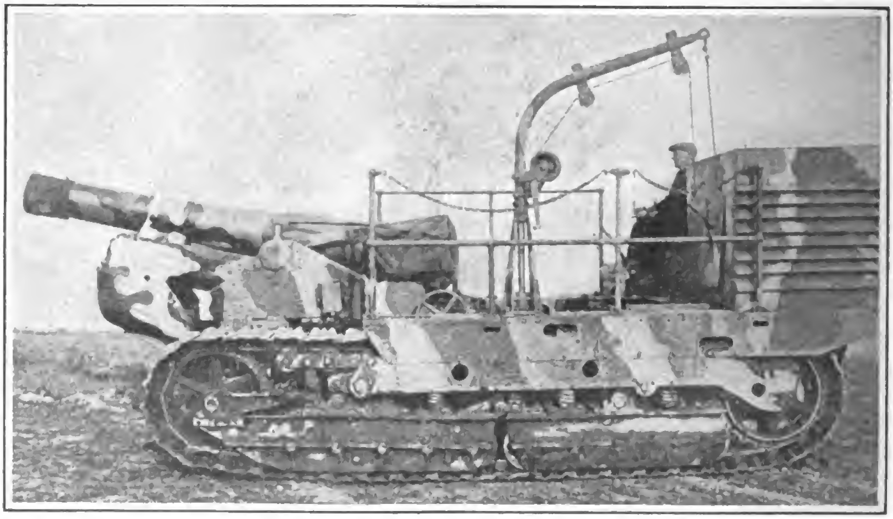
During a test the tractor gun climbed a 45-degree ravine wall and developed a speed of four miles per hour on level ground, demolishing trees and shrubbery just as do the monster tanks.

FIVE-TON ARTILLERY TRACTOR

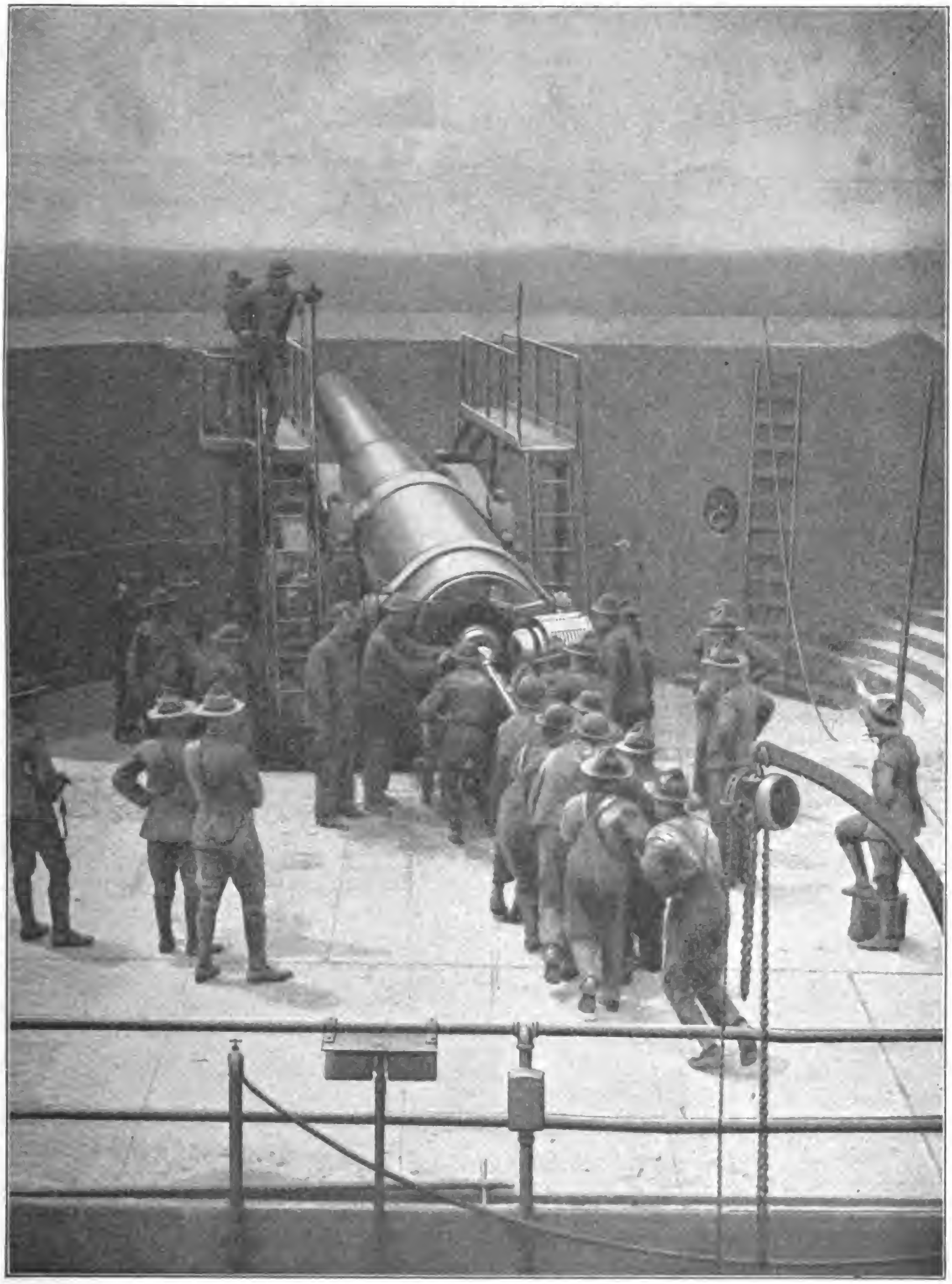
The 5-ton artillery tractor, developed and built in large quantities by the Ordnance Department, has put the horse out of business so far as pulling guns is concerned. Deep mud, shell craters, sand or logs cannot detain artillery when pulled by this type of tractor. The Ordnance Department has produced them in four sizes; namely, 2½-, 5-, 10- and 20-ton capacity. Automobile engineers and automobile factories with large production facilities made these tractors possible.

In addition to the artillery above enumerated, we possess some 9.2-inch mobile howitzers of the siege type, built from a British design; and it has been recommended that more of these be completed. This piece fires a 290-pound shell with a maximum range of about 10,000 yards, and for traveling it divides into three loads of about 14,000 pounds each, including the transporting vehicle. We have also got out a design for an 11-inch trench mortar with a maximum range of 4,500 yards.

The unexpectedly early termination of the



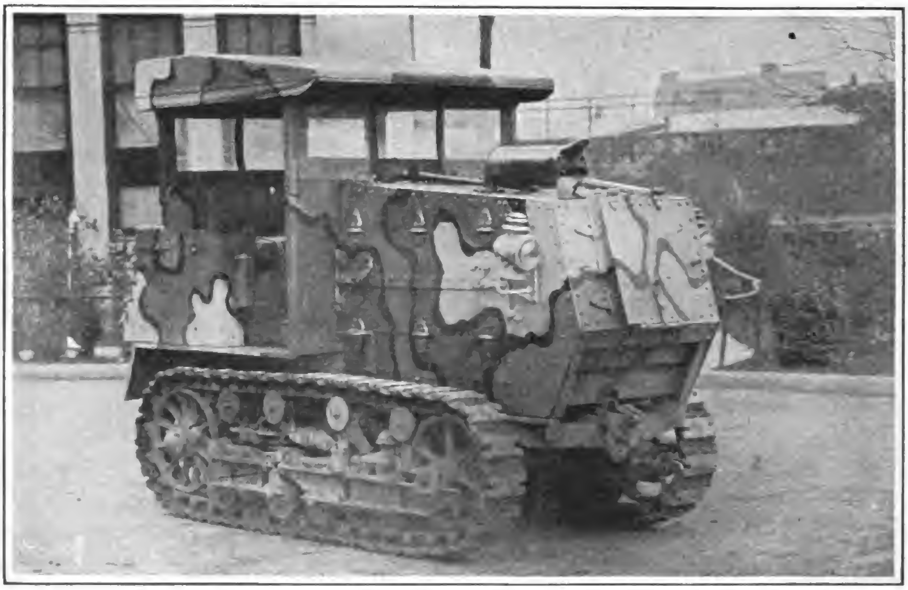
An 8-inch Howitzer with Caterpillar Mount



An American 12-inch Disappearing Coast-Defense Gun

An American coast-defense gun of 12-inch caliber in action. This gun is of the disappearing type; that is to say, it rises to the firing position and clears the parapet for only an instant, and following the discharge, drops again to be reloaded and aimed.

war left the country in an excellent condition as regards its capacity for the construction of all sizes of artillery in the event of a future war. Many of the plants were, of course, dismantled; but the great government establishments for the manufacture of ordnance on a large scale will be a permanent and immensely valuable asset to the country. The Ordnance Department is to be congratulated upon the way in which it rose to the occasion, put in operation the vast organization and built the equipment above described.



A 5-ton Artillery Tractor

WHAT OUR NAVY GUNNERS DID ON LAND

During the closing days of the year 1917, ordnance experts of the U. S. Navy, who had been closely watching the trend of events in the Great War, became intensely interested in the effect of long range bombardments. At a point about 28 miles from Dunkirk, the Germans had placed a large naval gun which opened fire upon that city, causing great damage, while at other points similar naval guns were carrying on their destructive work. It was reported that the Germans regarded long range bombardments as of such primary importance that they had dismantled several of their older battleships in order to bring the guns from them into action on the Western front. This tendency to increase the range of guns is demonstrated by the German innovation of a gun with a range of 75 miles, which fired a light projectile on the city of Paris (sometimes hitting that city —more often not).

While the Navy's limited testing facilities —i.e., proving ground with a range of only 18,000 yards—had never permitted the firing of its big guns at high angles of elevation, it was felt that the 14-inch 50-caliber naval rifle was superior to any German gun built, in range, accuracy, and striking power.

The 14-inch naval gun throws a 1,400-pound projectile at a muzzle velocity of 2,800 feet per second. With the Navy type of shell its maximum range is well over 40,000 yards or 22 miles, while using a special shell, designed for firing at extreme ranges, a range of about 53,000 yards or 29½ miles was possible.

Areas for destruction not hitherto touched were opened to a gun of this range. Troop centers, lines of communication, railroads, reserve store houses, and similar strategic points almost too numerous to mention could be destroyed by such guns. If mounted so that they could move rapidly from target to target,

their possibilities were almost unlimited. Guns of this type were urgently needed. Rear Admiral Ralph Earle, Chief of the Navy Bureau of Ordnance, recognized that need and saw that if a battery of 14-inch guns could be placed in action on the fighting front in France by the summer of 1918, they could render a real service to the armies.

It was decided that the emergency was such as to warrant using guns for this purpose that were intended for replacing damaged guns of the Fleet. Risks had to be shouldered in making this decision, but in time of war and need, responsibilities are heavy in all matters. It was, therefore, proposed to build mobile mounts for the guns (which meant railway mounts, for in no other way could the 95-ton, 14-inch gun be transported), completely equip them and place them in action in France before the close of the summer fighting in 1918.

In less than 30 days, complete designs were prepared which called for a battery of five guns, each gun-car train to be provided with a locomotive for hauling it, two ammunition cars, three berthing cars to house the operating personnel, a crane car, flat cars and gondola cars for carrying material, as well as other auxiliary cars. In addition to the five gun-car trains, a sixth train was provided to go independently from one gun position to another. The equipment totaled five gun cars, six locomotives, and 72 auxiliary cars of one sort or another.

The gun car consists of two large bridge girders, tied into a single unit, 72 feet long and weighing 68 tons. In the well between the two girders is mounted the 14-inch naval gun, which with yoke and breech mechanism weighs 95 tons, and the 30-ton gun slide, in which the gun moves back during recoil. The hydraulic recoil brake and the counter recoil mechanism are attached to the gun slide. The entire unit, consisting of girders, gun, slide, elevating gear, etc., is mounted on two sets of 12-wheeled trucks. The gun is arranged to fire at angles of elevation up to 15 degrees directly from the rails, and from a special steel and timber foundation at higher angles up to the maximum, 45 degrees. This foundation is prepared at the firing point in advance of the arrival of the gun car. The gun car is rolled over it and the foundation adjusted until the entire weight of the gun car is carried by it.

AIMING A BIG GUN BY MEANS OF A CURVED TRACK

Aiming is accomplished when firing from the rails by the use of a curved track. A simple traversing gear is provided to enable the gun to be aimed when it is on the pit foundation.

Every item went forward exactly as planned. Construction was pushed to the limit and all speed records were broken. The first mount was completed on April 25, 1918—just 72 days from the date the contract was signed—120 days from the date the designs were first started. This mount was proved at Sandy Hook, N. J., on April 30, 1918, where it met every test most successfully. June 1, 1918, saw the complete fulfillment of the first phase of the project; the Naval Railway Batteries were ready for shipment.

A slight delay occurred in the shipment of the batteries to France, for the German submarine *U-151*, which was operating off our coast, seemed to be especially anxious to prevent the shipment of the material. The submarine danger, however, was soon overcome, and by July 4, 1918, practically all the material was en route to St. Nazaire, France, where an erecting gang of American bluejackets were eagerly waiting to put the guns together and get them into action. The French, too, were just as eager to get the guns into action, so work on the assembly of gun cars No. 1 and No. 2, and their trains, was rushed, and they left for the front on August 17th and 18th, respectively.

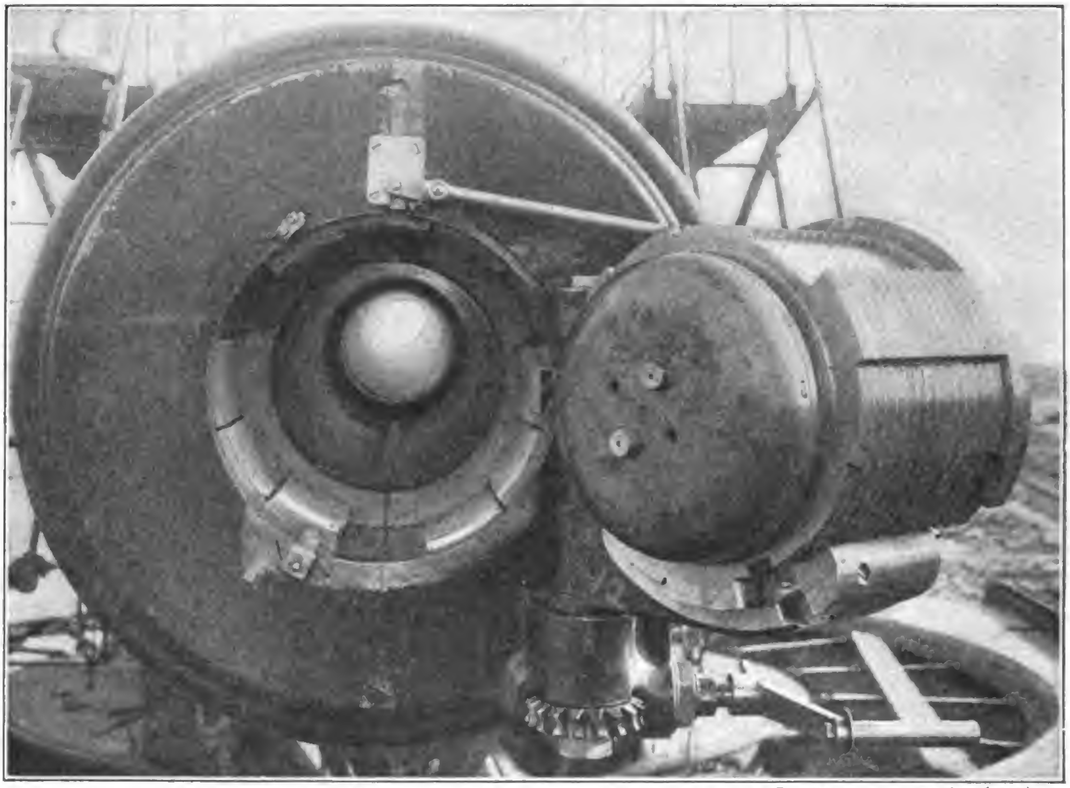
After a short trial trip over the railroads of France, and some preliminary tests, these guns were rushed to Laon, where, under the direction of the 10th French Army, they fired their first shots against the Germans on September 6, 1918—nine months and ten days from the date on which work was started.

CUTTING OFF A RAILROAD BY SHELL-FIRE

At Laon the guns inflicted great damage, their crowning achievement being the destruction of a crowded German moving picture

theater. One 1,400-pound shell hit the theater, leaving nothing but a deep crater in the ground, marked by scattered debris and identification tags of former occupants of the building.

Gun trains No. 3, No. 4, and No. 5, and the staff train, left St. Nazaire on September 12th, 13th, and 14th. After a short stay at the A. E. F. reserve artillery base at Haussimont, these guns proceeded to Thierville, near Verdun, and opened fire on Longuyon and Montmedy to interrupt the German main rail line of communication between Metz and Sedan. This railroad had long been immune from the fire of the Allied armies, as it had been, up to that time, well beyond the range of their guns. It lay at a distance of about 40,000 yards, 22 miles, behind the enemy lines, and was the only line available for troop transportation other than a line running far to the north, through Luxemburg. This line was an easy target for the 14-inch naval rifles, and so at Verdun, as at Laon, the accurate and destructive fire of these guns created havoc in the German lines. Troop movement along the Metz-Sedan line was seriously impeded, a single hit from one of these guns completely destroying three railroad tracks for a distance of over 150 feet, leaving nothing but a deep shell hole to mark the spot. Within a month after these great guns began their bombardment, at this point, the American Army pushed forward and definitely cut the enemy's line of communication.



Courtesy of Scientific American.

The Real Business End of a Big Gun

Here is seen the breech block of a large gun and a view up the bore. Shell and powder charge in the form of loaded bags are placed in the chamber, and the breech block swung into place by the crank shown in the lower right-hand corner.

The last shot from the batteries was fired by gun No. 4 at Thierville, near Verdun, at 10:59 a. m. on the morning of November 11, 1918. By a curious coincidence, the headquarters train carrying General Foch and the Allied Staff, which met the German envoys,

awaited the Germans on the identical siding near Compiègne from which the Naval Railway Batteries had fired their first shots just two months and five days previous.

Whatever the other accomplishments of our Navy and our Army in the great struggle just passed, history cannot fail to accord a place of prominence to the Naval Railway Batteries. Rear Admiral C. P. Plunkett, U. S. Navy, who commanded the expedition, can well be proud of its achievements. The Naval Railway Batteries were the only strictly American guns in the war, and were also the most accurate and the longest ranged, of *all* the mobile guns of the armies engaged in the war.

SUPER-GUNS

The Farthest Shooting, the Biggest, and the Most Powerful Guns of the War

IT was at the time that the British were being pushed back by the Germans in the spring of 1918 and the road seemed more or less open to Paris, that the Teutons sprang another of their surprises, in this case the long-range bombardment of Paris. The bombardment of Paris! It seemed impossible, to be sure; for the German lines were still some sixty miles removed from the French capital. Yet the shells arrived at regular intervals, and the populace soon realized that the city was indeed under shell-fire.

What manner of artillery was at the disposal of the Germans for this unheard-of bombardment? Was it an airplane flying too high to be seen? Or was it a concealed gun somewhere near Paris, operated by German spies or even by deserters from the Allied ranks?

The answer to these and other questions came a few days later, when French airplanes located the long-range German guns in the Forest of St. Gobain, near Laon. Three guns were being used by the enemy, and in order to escape detection they had arranged to fire a large number of other guns at the same time so as to throw the sound-ranging devices of the French off the track. However, a bombardment by long-range French artillery soon accounted for one of the German super-cannon, while another cannon is said to have been destroyed by an explosion. But, the third was still in operation and continued at its task of bombarding Paris for several months, off and on.

THE SMALLER THE GUN BORE THE GREATER THE RANGE

It will probably never be known just what the cannon was that the Germans employed in bombarding Paris. Indeed, when the armistice was signed and the Allied experts visited various parts of Germany, they did not come across the famous long-range gun. In the absence of definite data, it has been set forth by experts that the German gun, in all probability, did not differ materially from standard practice. Its long range was obtained by giving the shell an exceptional velocity, and this, in turn, was achieved by an exceptional caliber—the term used for denoting the proportion the length bears to the internal diameter. Some ordnance men offered the explanation that the German gun was probably a large sized naval gun, say of 15-inch bore, with a lining serving to bring the bore down to 9 inches, which was the diameter of the shells falling in Paris. By thus reducing the diameter while maintaining the same powder chamber, it would be possible to increase the velocity of the relatively small shell; and the big gun would be sufficiently strong to withstand the strains. Thus in the case of the standard 8-inch gun, the length is 50 calibers, and if a larger bore gun were converted to the 8-inch bore by a special liner, it would probably be possible to obtain a length of bore of 100 calibers.

However, while the actual construction of the long-range German gun may remain a

mystery for all time, the shells which fell in Paris serve to cast some light on this achievement of German scientists.

It was agreed among French artillerists that the shell probably weighed 220 pounds, and that its diameter was 8.2 inches. This last is one of the standard calibers of the German ordnance manufacturers; and it is quite probable that these are the correct size and weight. The shell proper was about 20 inches in length, and its walls were 1½ inches in thickness.

© *French Pictorial Service.*

Fragment of a German Shell That Traveled Seventy Miles

It was from fragments such as this one that the Allied experts were able to work out a probable design for the long-range German gun which bombarded Paris. The rifling bands of copper appear at *C* and *G*, and the permanent rifling at *B* and *F*.

One expert was of the opinion that, although the initial velocity was high, it was not excessively so; and he based his conclusion upon the laws governing the air resistance encountered by swiftly moving bodies. The atmospheric resistance at medium velocities of 1,200 to 1,500 feet per second increases as the square of the velocity, and, at the higher speeds, increases as the cube or fourth power, or even a higher power than that. He points out, on the other hand, that this resistance decreases uniformly with the decrease in density of the air—that is to say, with the increase in altitude. A suggestion that this decreased resistance is greater than has been supposed was found in the French experiments with a 380-millimeter gun, whose shells attained a height of 8 or 10 kilometers, with an increase of 10 per cent. over the calculated range.

Shell fragments made it possible to reconstruct the shell with a considerable degree of accuracy. There can be no question that, to throw a projectile of this size and weight to a distance of 75 miles, it was necessary to use a very high muzzle velocity. If, as already suggested, a 15-inch sub-calibered navy rifle was used for the purpose, it is certain that, because of the great length of the gun relatively to the sub-caliber bore, it would be possible to get the necessary velocity without using destructive powder pressures. Since the Germans used an 8.2-inch shell, the 15-inch Navy gun would have the length, for that shell, of over 90 calibers. But even with such length of bore, it has probably been found necessary to use a powder pressure much higher than the normal, which is from 18 to 20 tons to the square inch. With high powder pressures, the problem of sealing the base, so as to prevent a rush of the gases past the shell, becomes more difficult, and hence we find the Germans using two copper bands, one near the base and one well forward of the center of length of the projectile. Furthermore, the shell fragments seemed to reveal the fact that the Germans had trouble in making the rifling bands stand up to their work of giving the needed rapidity of rotation to the shell, for in front of each copper band a series of grooves had been cut in the shell to match the rifling of the gun.

WHAT THE SHELL FRAGMENTS DISCLOSED

There is nothing novel in rifling the shell, for, as a matter of fact, in the early days

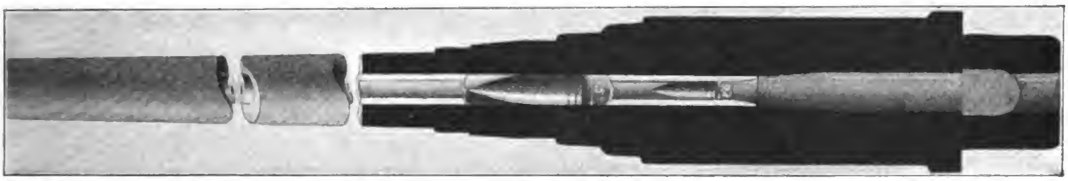
of the development of rifle ordnance in Europe, and particularly in England, the projectile was provided with studs made of a soft metal, such as zinc or copper, which served to take the rifling of the gun and give the desired twist. Another method we may mention here was to make the bore of the gun hexagonal and form a corresponding hexagonal surface on the shell. A well known example of this was the Whitworth projectile.

We are told that the pieces of the projectile which were recovered in Paris are of very fine metal, extremely hard and showing a shiny fracture. The metal seems to be in the class of vanadium steels. Recovered fragments proved that the shell cavity is divided into two portions by a heavy horizontal diaphragm, which is perforated. It seems that this arrangement is similar to that used in the 420-inch German shell, and it is supposed to be done in order to diminish the heavy compression set up by the explosive filler due to its inertia when the shell is fired. According to a French authority the action is sufficient sometimes to cause premature explosion. This is rather puzzling, because the shell filler that we use is absolutely insensible to shock—in fact, it is capable of being carried through a thickness of armor equal to the caliber of the shell without detonating. In the days when black powder was used as a filler, it sometimes happened that shock would set off the charge before the shell left the gun.

The fuse is at the base of the projectile, which is closed by a double plug. The base of the projectile is somewhat rounded, supposedly to offer some helpful effect in reducing air resistance. The nose of the projectile, it will be noticed, is not ogival but blunt. It is threaded on its periphery, and upon the head is screwed a light, steel, false nose, the curve of which is struck with a very long radius. This false head, of course, is nothing new, and, in fact, it is used in most of our large modern projectiles. Its object is to reduce head resistance, etc., and tests have shown that a false head of this kind will greatly extend the range.

The light weight of the shell, the rifling cut in the shell itself, and the double gas check provided by the two copper bands, present cumulative evidence that the powder pressure is high and the muzzle velocity also.

The bombardment of Paris was carried on in a desultory fashion, with intermissions which suggest considerable trouble with the gun itself.



How a Super-Range Gun May be Made from any Standard Gun

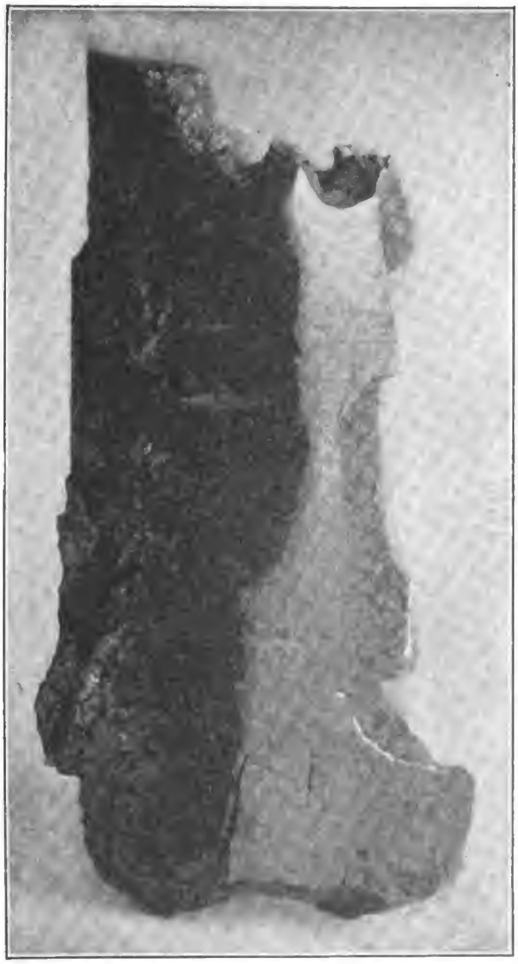
How a super-range gun may be made from any standard gun. In this case a 15-inch gun is shown with a special liner, reducing the effective bore to 9.4 inches. At first it was believed that the Germans had made their long-range Paris guns in this manner. The effect of reducing the bore of a big gun is the same as lengthening it, hence giving a higher velocity and proportionately greater range to the shell.

WHY LONG-RANGE GUNS ARE POSSIBLE BUT NOT PRACTICAL

Long before the Germans began to throw shells into Paris from a distance of 75 miles, it was well understood among ordnance officers that such a feat, if any one should care to attempt it, was perfectly possible. The introduction of slow-burning, perforated powder and the great improvements in gun steel, opened up large possibilities of increasing the range of artillery, and the ranges for heavy guns, both naval and military, quickly ran up 10, 15, 20, 25 and even to 30 miles.

Because military men, in considering what range to give to their weapons, always think in terms of military objectives of limited area,

such as gun-pits, crossroads, ammunition dumps, airdromes, etc., for the actual hitting of which observation from an elevated position or by airplane is necessary, no one had thought of building guns to throw shells to such distances as would prevent observation of their point of fall, and it took the German mind in its gradual ascent, or rather descent, from poison gas to submarine piracy, to conceive the idea of building a gun that could throw shells in a haphazard fashion into the city of Paris—a target so large that even from a distance of 75 miles it would be impossible to miss its most important centers. The Germans knew that the small size of the shell,



Courtesy of Scientific American.

A Fragment of One of the German Long-Range Shells Which was Shot into Paris

8.2 inches, and the lack of observation, would render the material damage done out of all proportion to the cost in time, money and trouble of building and operating a 75-mile gun such as they planned. It was not material, but moral, damage that the Germans aimed at, and in this, as in so many other cases of terrorism on their part, they failed ignominiously.

The Allies built no super-range guns during the war—not because they were unable, but because they had no wish to. They realized, when it came to a question of retaliation for German bombing and shelling of fortified cities, that the airplane is infinitely more efficient than the super-range gun; that for the cost of one shell dropped upon a city by the gun, over one thousand times as much high explosive could be dropped from bombing airplanes, and let fall with incomparably greater accuracy.

It was in order to prove how extravagant in time, cost, and labor is a super-range gun in proportion to the damage it can do, that the Ordnance Department of the Army designed a 10-inch gun, which was to have a range of between 120 and 125 miles. With a view to getting accurate data on such a gun, its design was proceeded with exactly as though it were to form the basis of working drawings and specifications for construction at the gun factory. The results of this investigation are shown in the surprising sketches and tabulated data of this gun.

It should be understood, just here, that the dimensions of the gun, weight of powder, shell, gun, etc., and the general ballistic data are the result of close calculation. The method of mounting the gun, as shown in the sketch on page 51, is merely suggestive and was never worked out in any detail. Broadly stated, the problem is one of burning a sufficient amount of powder in a gun of sufficient length to maintain a mean pressure down the bore of the gun sufficient to produce, at the muzzle, the enormously high velocity necessary to carry the shell for a distance of 125 miles. With a 10-inch shell of 400 pounds weight, and a chamber pressure of 22½ tons to the square inch and a muzzle velocity of 8,500 feet per second, it was found that the angle of departure which gave the best results was 55 degrees and that under these

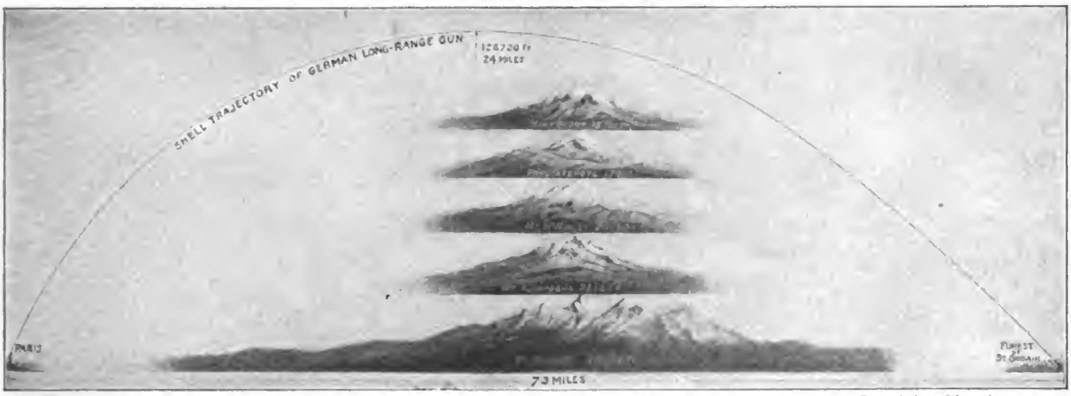
conditions the maximum range would be 121.3 miles.

COMPARISON OF A 121-MILE GUN WITH A GUN OF STANDARD SIZE

	Elswick Standard Gun	Theoretical Super-Range Gun
Caliber of gun........	10 inches	10 inches
Length of gun........	42 feet	225 feet
Weight of gun........	38 tons	325 tons
Weight of projectile...	500 pounds	400 pounds
Weight of powder charge............	200 pounds	1,440 pounds
Powder chamber pressure..........	40,000 lbs. per sq. in.	45,000 lbs. per sq. in.
Muzzle velocity.......	3,000 foot-seconds	8,500 foot-seconds
Muzzle energy........	31,000 foot-tons	201,500 foot-tons
Maximum range......	25 miles	121.3 miles
Angle of departure....	45 degrees	55 degrees
Angle of fall..........	50 degrees	59 degrees
Summit of trajectory..	7.8 miles	46 miles
Velocity at summit....	1,550 foot-seconds	2,600 foot-seconds
Terminal velocity.....	1,695 foot-seconds	2,750 foot-seconds
Time of flight........	1 min. 37 secs.	4 min. 9 secs.

of departure, for the reason that at 55 degrees the shell follows a shorter path through the denser atmosphere, say in the first 10 miles, than it does at 45 degrees, and hence it emerges into the upper atmosphere with a higher remaining velocity.

The dimensions of the gun are certainly very startling, particularly in comparison with a standard Elswick 10-inch gun. Its length is 225 feet as against 42 feet; the powder charge goes up from 200 pounds to 1,440 pounds; the powder pressure goes up from 20 to 22½ tons per square inch; the muzzle velocity, which in the standard gun is 3,000 feet per second, in the super-range gun is 8,500 feet per second; and although the shell in the standard gun is 25 per cent. heavier, or 500 pounds as against 400 pounds, the muzzle



© *Scientific American.*

The Flight of the German Long-Range Shell

In the course of its flight from the Forest of St. Gobain to Paris, the German long-range shell rose to a height of 126,720 feet—24 miles—or sufficient altitude to clear the five highest mountains in the world, piled one atop of the other. The penetrating power of the shell was more feared than its explosive force.

THE FLIGHT OF SHELLS THROUGH SPACE

An interesting fact brought out by the investigation was the determination that an angle greater than 45 degrees would give the greatest range. In previous years with guns of extreme ranges up to 21 miles, where the line of flight lay entirely in the lower and denser strata of the atmosphere, it was found that 43½ to 45 degrees was the correct angle for maximum range; but in these super-range guns, where the shell quickly passes into the higher rarefied atmosphere, it was found that there is a positive gain in increasing the angle

energy, which is 31,000 foot-tons in the standard gun, is 201,500 foot-tons in the super-range gun.

The super-range shell is fitted with a long, tapering, false head to reduce the end-on resistance of the atmosphere, and under the enormous velocity, in a few seconds it has passed up through the 10-mile belt in which the bulk of the atmosphere is found, and sweeps with high remaining velocity into the tenuous atmosphere above. Here there is practically no retardation due to the atmosphere, and its loss of velocity is mainly due to the component of the pull of gravity acting

tangentially to its path of flight. In our bird's-eye view, the gun is supposed to be set up at the Aberdeen Proving Ground, about 20 miles north of Baltimore, and is aimed at Perth Amboy, opposite the southerly tip of Staten Island in New York Harbor. The shell rises steadily until it has passed over Wilmington and is within a few miles of Philadelphia, over which it passes at an elevation of 46 miles, and here it still has a remaining velocity of 2,600 feet per second. Then, as it commences to fall, gravity begins to act in its favor and probably more than counteracts the resistance of the tenuous atmosphere, with the result that its velocity increases again until it gets within ten or twelve miles of the earth, when retardation again takes place, the final arriving velocity being 2,750 feet per second and the angle of fall being 59 degrees, which is four degrees greater than the angle of departure.

Courtesy of Scientific American.

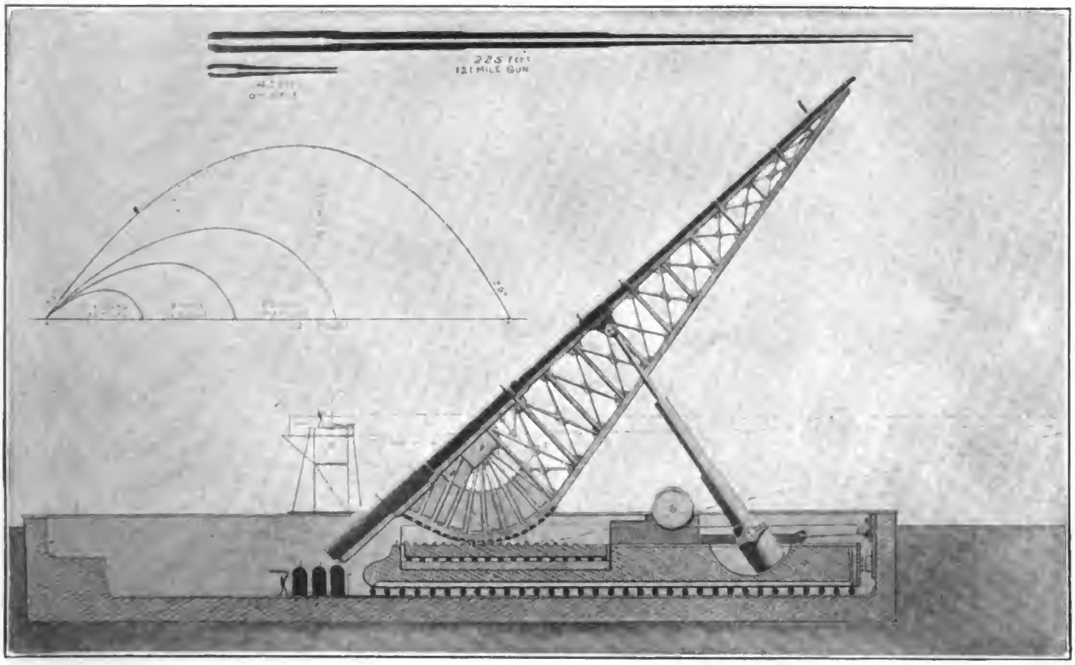
Airplane View of the Shell Flight of the Hypothetical 120-mile Gun

The elapsed time of flight would be 4 minutes 9 seconds.

Since the total length of the gun would be 225 feet, it would have to be built in, say, four lengths, and the parts screwed together. This is perfectly feasible; in fact, gunmakers have used the method in some of their guns with complete success. The weight of the piece would be 325 tons and this, coupled with the energy of a recoil corresponding to a muzzle energy of the shell of over 200,000 foot-tons, would call for some very original and clever engineering construction in the mounting of the gun. Because of its great length and weight, it would be impossible to mount the piece on trunnions located at its center of gravity, for the gun, being elastic, would bend under its own weight and, when fired, it would have a violent whipping action. So it would have to be carried on a truss, or rather, on the apex of a triangle consisting of three trusses—two side trusses and one connecting the bottom chords of the side trusses. Elevation and depression of the gun would be accomplished by forming the bottom chord of the trusses towards the breech of the gun into two broad curved and toothed bearing surfaces, by means of which the gun and its carriage would roll upon a suitable foundation path in much the same manner as a bascule bridge. The gun truss with its counterweighting would probably be found to weigh at least as much as the gun, or, say, 650 tons, so that a very massive mount and powerful means of checking the recoil would be necessary. The gun carriage platform would have to be mounted upon several parallel tracks to distribute the weight, and in addition to sliding friction through blocking interposed be-

tween the under-side of the carriage and the rails, additional retardation could be provided by means of steel cables, anchored to the forward face of the gun-pit, and leading back to winches on the gun platform, controlled by powerful friction brakes. The elevation and depression of the gun might be controlled by a telescoping hydraulic plunger, as indicated in our drawing.

Our thanks are due to the Army Ordnance Department for the opportunity to present this very interesting theoretical study of the possibilities of long-range artillery. The results most dramatically prove the futility of building such ordnance. A single gun, as pointed out to us by the ordnance officer at Washington who made the calculations for this gun, would cost probably about $2,500,000. The best it could do would be to land a 400-pound shell, containing about 60 pounds of high explosive on a target 121.3 miles away, whereas a bombing plane, costing about $30,000, would land a 1,600-pound bomb on the same point with greater accuracy of aim.



Courtesy of Scientific American.

A Freak Gun With a Range of 121 Miles

This gun was designed in the United States to prove that the German super-range was not as remarkable a feat as was generally supposed.

A GUN WHICH WRECKED FORTS WITH ONE SHOT

The extreme publicity given the long-range German gun has quite overshadowed the French 520-millimeter gun, which after all remains the most powerful gun in existence. Whereas the German piece throws its shell 75 miles, the French gun is relatively a howitzer hurling a huge shell a comparatively short distance. But at this distance it produces results; practically speaking, it is a fort wrecker of proved powers.

For some time there had been rumors of a 520-millimeter gun employed by the French artillerists, but ordnance experts and others familiar with the difficulties in the way of producing such a powerful piece of mobile artillery did not place much credence in the unofficial descriptions; they preferred to wait for some definite evidence.

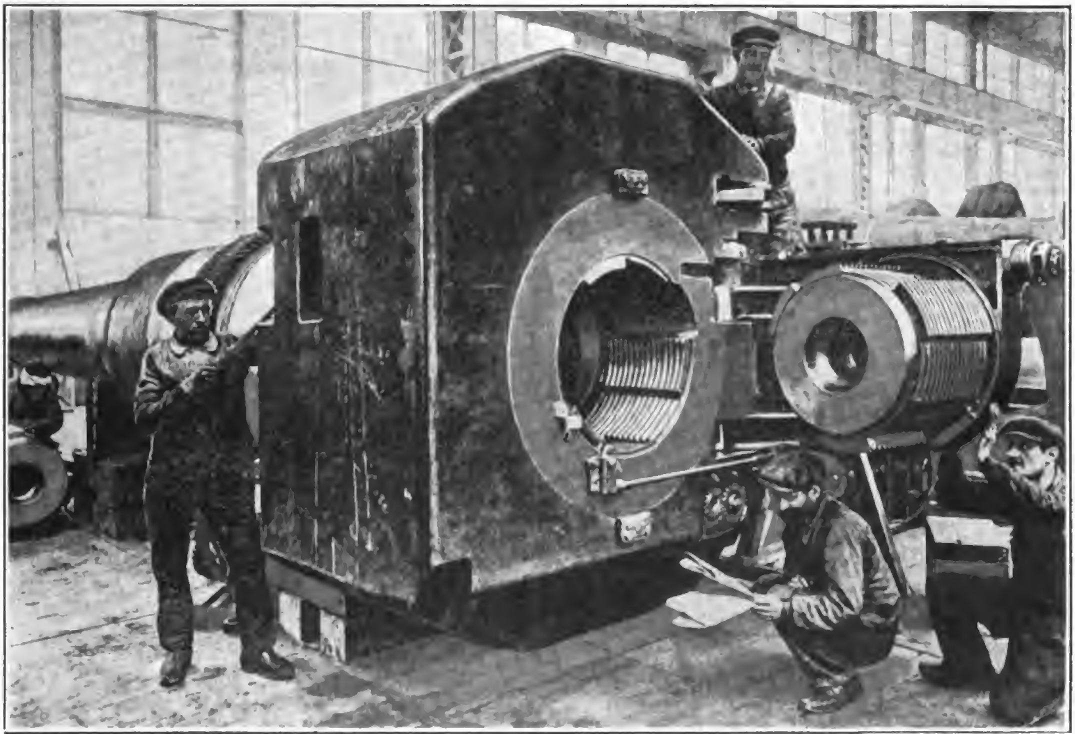
It was not until the French official films presented the 520-millimeter gun to American audiences that ordnance experts and others

were convinced that the huge mobile howitzer was a *fait accompli.*

It appears that the gun is a howitzer mounted on a railroad carriage, and fires a shell measuring 20.47 inches in diameter. As a fort wrecker, this gun is undoubtedly without peer, the German 420-millimeter and the Austrian 300-millimeter howitzers having been outdone by a good margin. During the French attack on Fort Malmaison it is reported that a single 520-millimeter shell crumbled this permanent fortification upon which the Germans had spent so much time and labor.

The German 42-centimeter gun was designed primarily for reducing the Belgian fortifications; but also it had a decided moral effect. The French in getting out this huge weapon also had a double object in view. It was encouraging to the French troops to know that their artillery included a gun which was immeasurably more powerful and destructive than the heaviest guns of the enemy; and, conversely, it was depressing to the German troops to know that their own artillery was greatly outmatched, particularly when they were eye-witnesses of the appalling destruction wrought by a single hit with one of these shells.

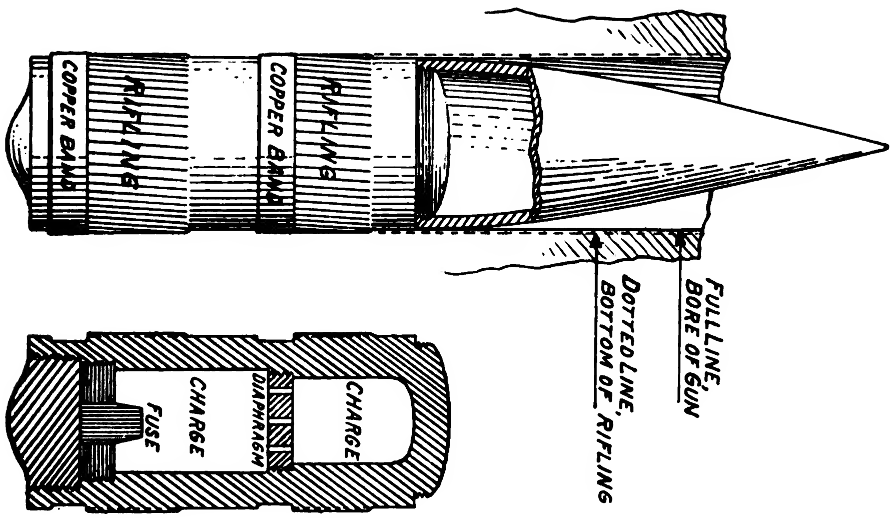
The shell must be at least six feet, and possibly six and a half feet, in length. It has the characteristic finely-tempered head of the French shells, and also there is the usual slight tapering of the after portion. The weight has been given as 3,200 pounds. If this be so, it is just 1,000 pounds heavier than the shell of our new 50-caliber, 16-inch naval gun, which weighs 2,200 pounds. Necessarily, the gun itself must be exceedingly heavy. Our 16-inch, 35-caliber rifle, now at Panama, weighs 284,000 pounds; and since this French piece is probably 30 calibers, and may even



The Largest Gun Used in the World War

It was not the Germans but the French who employed the largest gun during the war. The French built several howitzers of 520-millimeter bore—nearly 21 inches. Here is the breech end of one of these guns.

be 45 calibers in length, its weight must be somewhere around 400,000 pounds. Of course, a gun of this weight has to stick to the railways, and it has necessitated the designing of a special carriage of great strength to carry the enormous load and stand the heavy stresses of the recoil.



Courtesy of Scientific American.

The Long-Range German Gun Shell that Bombarded Paris

This drawing shows the probable construction of one of the German shells used in bombarding Paris from a distance of some seventy miles. It will be noted that the shell carries two soft copper bands which take the rifling of the gun, as well as permanent rifling grooves in the steel. The copper bands are evidently intended as gas checks, while the permanent rifling takes the rifling of the barrel.

A GUN DESIGNED TO DESTROY BATTLESHIPS WITH ONE LUCKY SHOT

In the continual race between gun and armor, the gun easily maintains its lead. Even the 11-inch and 12-inch guns of the German fleet found no difficulty in penetrating the armor of the British ships; and it is only because the heavier British projectiles carried a defective delay-action fuse that they failed to get through the heavier German armor. In view of this superiority of the gun, it may seem surprising, at first thought, that the size and power of heavy artillery have been increasing during the war, but the fact is they did increase, and at an altogether extraordinary rate.

The following table showing the continual enlargement of calibers and corresponding increase in the weight of projectiles, shows the extent of this development at a glance. During the past decade we have seen the heavy guns of battleships and battle cruisers grow from the 12-inch gun, throwing an 850-pound shell, to the British 18-inch gun throwing a veritable monster weighing 3,600 pounds—an increase of 50 per cent. in caliber and about 450 per cent. in the shell.

TABLE SHOWING INCREASING SIZE OF GUNS

Caliber of Gun	Weight of Shell
12" naval	850 pounds
14" "	1400 "
15" "	1925 "
16" "	2100 "
18" "	3600 "

According to Sir Robert Hadfield, who specializes in the manufacture of armor-piercing shell, the 3,600-pound projectile of the two 18-inch guns which were first mounted on the battle cruiser *Furious* and later on one of the British monitors, are by far the heaviest armor-piercing shells ever fired. The gun, according to *Engineering*, weighs about 150 tons, and at its maximum elevation of 45

degrees it can throw its projectile, which is 18 inches in diameter and 7 feet in length, to a distance of about 50,000 yards, or say 30 miles. In the trials of the gun, the shell, fired at a velocity equivalent to a range of about 14 miles, perforated a hard-faced plate 18 inches thick, which means that at that range, which exceeds, by many miles, the most extreme battle ranges of the late war, it would pass through the heaviest armor afloat.

The perforating power of the shell is such that at point-blank range, it would pass through 41 inches of face-hardened armor, which is equivalent to a mass of steel 54 inches in thickness. At 10 and 20 miles respectively, it would perforate 22 inches and 12½ inches of face-hardened armor, and at the extreme range of 30 miles, it would get through nearly 12 inches of face-hardened armor.

Now, if in this huge shell the proportion of weight of high-explosive filler to weight of shell is 15 per cent., it would mean that when the shell burst within a ship, over 3,000 pounds of steel would be hurled in every direction under the bursting energy of about 500 pounds of high explosive.

But how can a ship be hit at such distant ranges, where she would be hull down to the ship that was firing? The answer is to be found in the modern naval method of directing the gun-fire by airplanes launched from the ship itself. These, circling high above the enemy and spotting the fall of the shells, would send the results back to the firing ship. At these ranges shells would fall at a very steep angle, and the problem that is worrying the naval constructor to-day is how in the name of the impossible he is going to provide sufficient deck armor to keep the shells out. It begins to look as though the only defense of the future will be high speed and the steering of the attacked vessel on a continuously sinuous course.

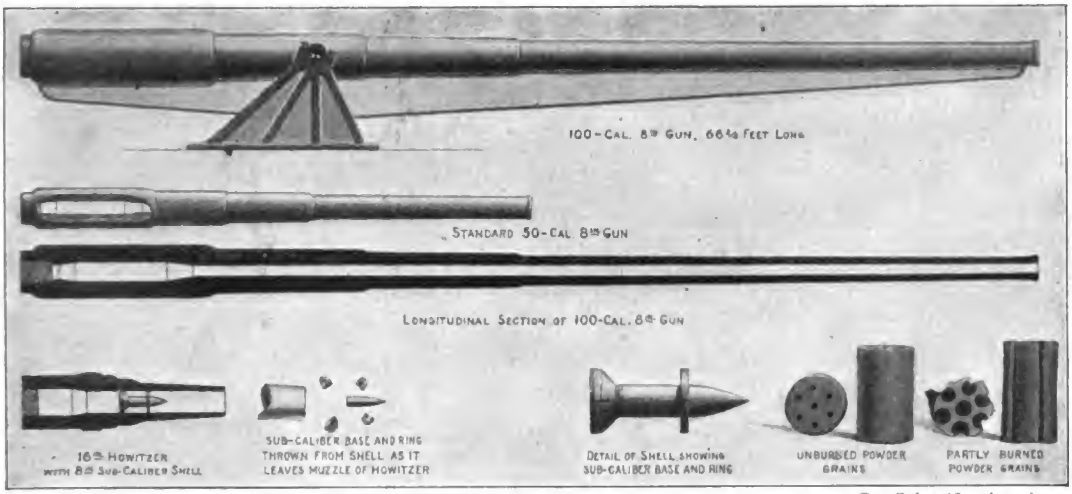
HOW BIG GUNS ARE MADE

A Non-Technical Statement of the Major Considerations that Govern this Highly Technical Business

WAY back in the days when gunpowder and cannon were really new, the cannon, so far as its construction went, was nothing more or less than a barrel. It was made up in quite the same fashion as this familiar container, of several wooden staves strapped together with rope or chain or wire. Of course it was not gas-tight, and every time it was fired there was a large escape of powder pressure through the interstices between the staves; and it was not capable of withstanding any alarming amount of pressure anyway. But the powders of the fifteenth century were quite as crude as the cannon in which they were shot; so while the latter sometimes burst under the strain, they were on the whole fairly satisfactory.

No notable improvement in gunpowder itself was made until the nineteenth century was well along toward its close; whatever of better performance was got out of the gun during the interval of five hundred years, more or less, that came between the discovery of powder and the invention of modern explosives, was due entirely to improvement in the details of powder making and to better guns. The whole thing was closely limited by its own narrow applicability. Until powders were produced which gave vastly greater pressures there was no demand for guns of extraordinary strength; until the round shot was replaced by something that would fly true at high velocities there was no call for great improvement in gun or powder; and until a new technique of making guns was developed there would be no utility in changing the powder or the shot so that greater muzzle velocity and greater range would result. In the good old days, it must be remembered, there was no such thing as effective fire at long range; the initial velocity was low, the projectile was a solid ball, the velocity fell

off so rapidly that even at a couple of hundred yards the ability of the shot to do damage was problematical. Even naval warfare, conducted with the heaviest guns that could be made, was a short-range affair; and commanders felt that they could hardly inflict serious damage upon a hostile vessel until they were actually at boarding range. So battles were fought on this principle; ships would maneuver and fire at each other from several hundred yards, perhaps; but the real fight



Methods of Making a Long-Range Gun

When the news of the long-range bombardment of Paris first came to the United States, artillery experts got busy figuring how the remarkable German guns were built. One of the suggestions was that the Germans were using a standard naval gun, which, however, they had relined for a 9.4-inch caliber. Another suggestion was that they had a special sub-caliber shell, arranged to fit in the big gun but provided with breakaway base and rings which would fall off after leaving the muzzle. In the accompanying illustration is shown a long-range 8-inch gun, with reinforcing girder under the barrel, and a comparison between a standard 8-inch gun and the theoretical long-range 8-inch gun. The lower illustrations show a sub-caliber shell scheme and grains of powder of the slow-burning variety, which would probably prove very effective in a long-range gun.

came when they had fastened grappling irons upon one another, and served their guns with their muzzles practically aboard the hostile craft. Under such circumstances the shot penetrated; at longer ranges they did little more than deal a blow from which they rebounded with a minimum of damage.

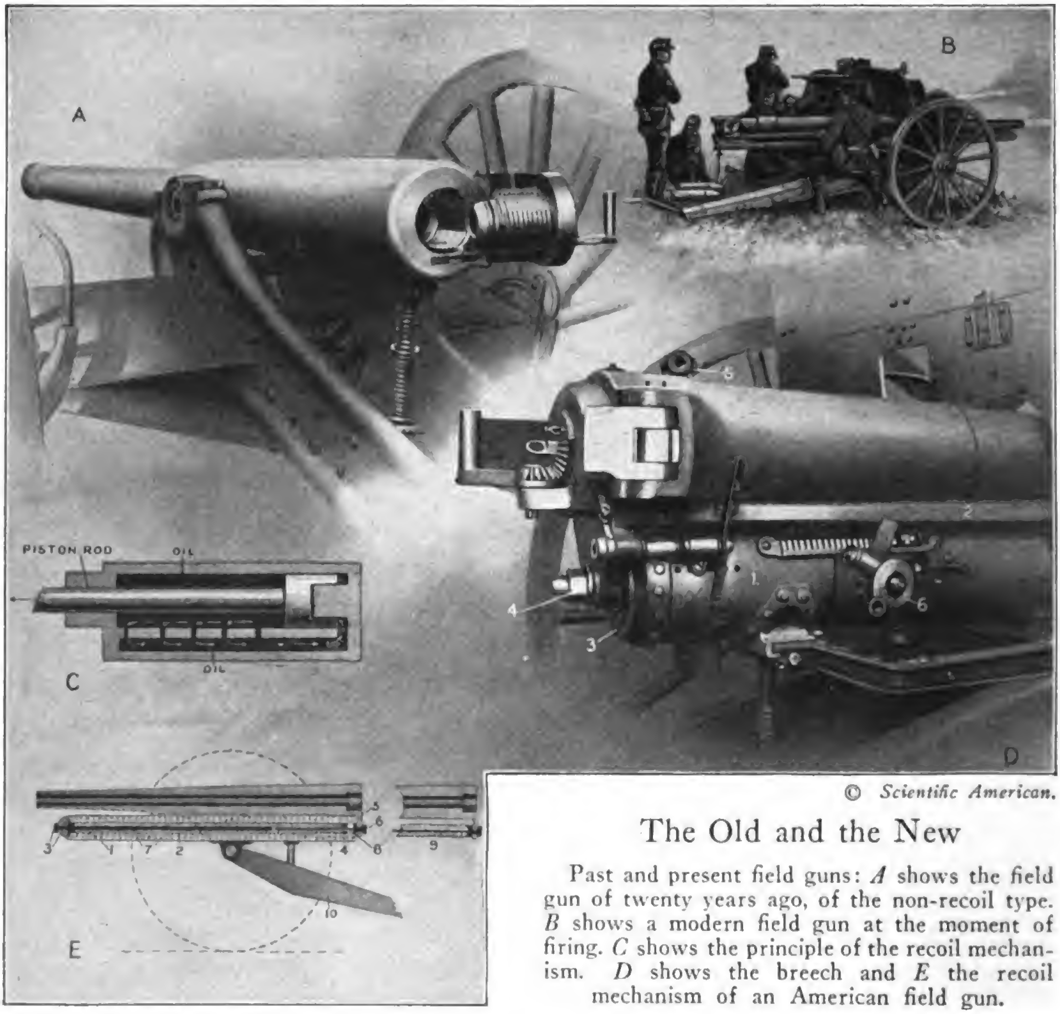
So for five hundred years the gun was, constructionally, just a bottle of cast iron; and it was made much as any other bottle of cast iron would have been made. But with the discovery of powders which give chamber pressures that would disrupt a simple flask of cast iron, it was necessary to change the principles of gun design to make the new explosives available. The result has been the modern forged gun.

THE MODERN GUN, WITH TUBE AND JACKETS

The general principle of this gun is that it is not cast in its final shape at all, and that it is not even made in a single piece. The inside bore, the surface traversed by the projectile after the charge is fired behind it, is indeed in one piece. But this piece is comparatively light, and would not begin to support the pressures developed in the powder chambers. So at the rear of the gun more metal is piled on, and this process once begun has no limits. We can put as many bands of metal about a gun tube, and have them reach as far forward toward the muzzle, as may be necessary to provide for safe use of any powder which we may have it in mind to use, with any pressure it may be capable of developing.

The gun tube proper is cast in the form of a cylindrical bar or rod of proper length and thickness—the latter dimension being, in the

first place, considerably in excess of what is finally desired, to allow for subsequent machining. After a certain amount of annealing, hardening and tempering the bore is created by drilling through the bar, from end to end, a hole somewhat *smaller* than the final caliber of the gun—again to allow for the internal machining necessary in this hole. Then more tempering and annealing and hardening, with now and then a machining to bring the tube closer to its final size. The heavy cuts come first, of course, followed by lighter ones as the successive treatments make the metal ever harder and tougher. The rifling is done by a special machine not unlike a drill, which cuts the spiral groove in three or more operations—a roughing cut and two or more finishing cuts. And then the tube is ready for its jackets.



© *Scientific American.*

The Old and the New

Past and present field guns: *A* shows the field gun of twenty years ago, of the non-recoil type. *B* shows a modern field gun at the moment of firing. *C* shows the principle of the recoil mechanism. *D* shows the breech and *E* the recoil mechanism of an American field gun.

The number and size and shape of the outer members of the gun depends wholly upon the service to which it is to be put, since that in turn determines the initial and subsequent powder pressures. Every one who has seen big guns must have noted that some have a practically uniform taper from breech to muzzle, while others are built up to a great thickness at the rear and slope off rapidly to a moderate diameter, after which they taper gradually to the muzzle. The determining factor is whether the powder burns rapidly or slowly. In the former case the greater proportion of the burning is effected before the shell has traveled far down the bore; the

pressure is therefore high, not only in the powder chamber where there is combustion without any space at all for expansion, but perhaps in the entire rear fourth of the gun, in which the products of burning from the greater portion of the powder are momentarily confined. If on the other hand the powder burns slowly, the space offered for expansion increases more rapidly, as compared with the increase in the mass of gas in the bore; and the pressure is more nearly uniform throughout the length of the gun.

PUTTING THE METAL WHERE THE PRESSURE COMES

It will be understood that the pressure is always highest in the combustion chamber. Also, the total pressure developed along the entire bore is not greatly different in two guns of similar charge; it is merely the distribution of this pressure that differs. If one gun has much greater pressure in the rear section than a second, the second will have a pressure which decreases so much more slowly that in the forward quarter it will be notably in excess of the corresponding pressure in the first.

Whatever the pressure, enough metal has to be piled on to withstand it. This is effected in just one way—by shrinking bands of steel about the gun. This process is completely described when it is named—it consists merely in applying great heat to a steel hoop which at normal temperature would not quite go on the tube. Under the expansion thus developed the hoop *will* go on, with a hair's breadth to spare; and then it cools and shrinks and grips the tube literally with a grip of steel. The technical difficulties in making a single jacket the entire length of the gun would be serious, so this is not attempted; the length of the tube is covered by several separate jackets, which interlock at their junctures so that there can be no slipping. Also it would be a matter of much difficulty to shrink on a jacket of excessive thickness, so the sections of the tube which require a lot of reinforcing have several jackets applied to them, one above the other.

There is just one more point to consider. Whatever of wear the gun undergoes is localized on the inside of the tube. When this is completely ruined by gas erosion and metallic friction the entire ensemble of jackets is still as good and as serviceable as it ever was. The obvious thing to do under these circumstances is to slip out the old tube and insert a new one—to reline the gun, in other words. Formerly this was a matter of great difficulty and expense, and was only attempted because after all it was a little bit cheaper than scrapping the whole outfit and building a new gun. Preparation of a new tube was simple enough; the hitch came in trying to free the jackets from the tube.

One of the Large French Shells

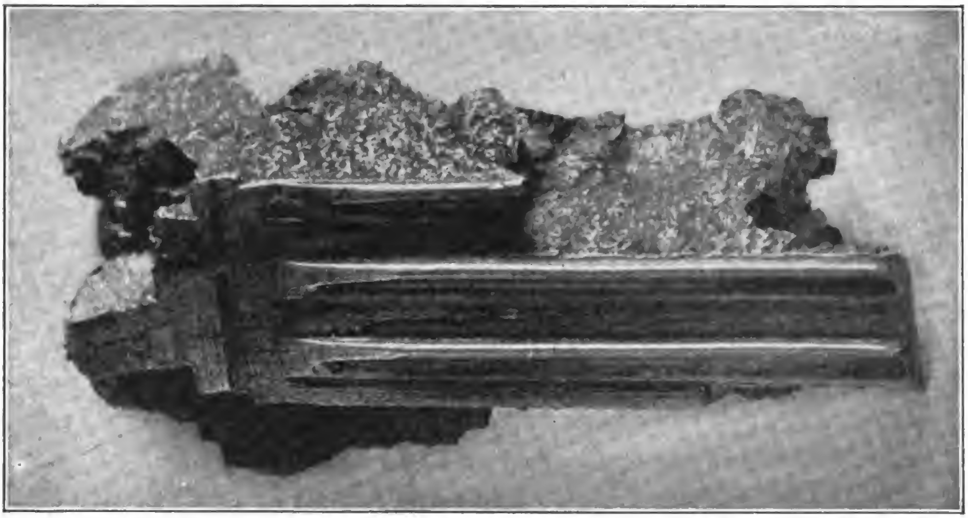
A graphic demonstration showing how these huge projectiles, which were hurled daily into the German lines, compare in size with a man.

THE TAPERED GUN-TUBE

When you pull out a nail the big pull comes in getting it started; after that it is easy. The same remark applies to a screw that is well set. The reason for this is that the nail and the screw taper, so that when the pressure that holds them tightly in place is once relieved, it is relieved for good; the moment the nail or screw is withdrawn a small fraction of its length, it no longer fits so snugly. But in the beginning the gun tube was made with its outer and inner surfaces straight and parallel, so that the last half-inch of withdrawal called for just as much force and just as much delicacy of handling in order to insure that the jackets be not damaged, as did the first half-inch.

So to-day the gun-tube is slightly tapered *on the outside*. When the jacket is heated, we then get the same condition that applies in the removal of a nail. A few powerful taps on the small end of the tube start it on its way out; and then it is simply a question of handling the weight of the tube, which to all intents and purposes is suspended freely in the cradle offered by the jackets. Incidentally, it is now clear why the jackets must interlock sufficiently to make them in effect a single piece; for after the removal of the tube, while awaiting the insertion of a new tube, they must stand up as a single piece, without the customary support from within which the tube affords when in place.

Before leaving the subject of gun manufacture, it is in order to mention one style of construction which for a time seemed perhaps destined to attain supremacy, but which with the advent of better steels and better technique for handling steels has had to go into the discard as unnecessarily expensive. Instead of a multiplicity of jackets, the suggestion was brought forward and tried with success that the inner tube be wound around and around with wire, over which a single outer jacket would be shrunk merely as a protective coating. It was estimated that the tensile strength of the wire would oppose a resistance to the powder pressure quite as effective as that of the solid metal. Indeed, for a time the wire-wound gun was made and used with some freedom.



Courtesy of Scientific American.

Another Fragment of the German Long-Range Shell

BULLETS VERSUS ARMOR

How Metal Was Used in the War for Protection Against Rifle and Machine-gun Bullets, as Well as Shell Splinters

FROM the day the horrified jackies of our old Navy watched their round shot bounce off the armored sides of the *Merrimac,* ballistic sharks and armor experts have striven assiduously to produce the fabled condition of an irresistible force meeting an immovable body. The *Merrimac* was efficient not because her armor was anything but crude railroad iron, but simply because this sufficed to stop the inefficient missiles of the day. A tug with a modern 3-inch quick firer could have stood across Hampton Roads and whipped the hind sights off the poor old turtle-back without taking a scratch.

From that hour to this, and with the end not yet in sight, projectile maker has gone armor manufacturer one better, only to have the other "see and raise" him, with the process repeated in wearisome iteration. And now the argument has been transferred to land, becoming the case of the rifle and machine gun versus the steel shell for men, cars, planes and tanks.

THE SEE-SAW OF MILITARY TACTICS

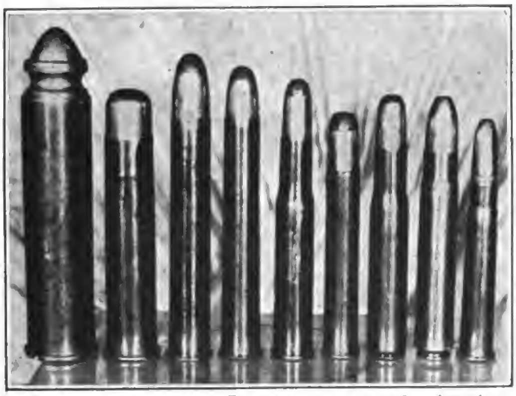
After every war, authorities and near-authorities emerge with a full list of the conclusions drawn therefrom, which are final and admit no argument. Thus the Boer War did away with the bayonet. The British were very bitter about this weapon. What was the bally use, they asked, of a bloomin' bayonet when the bloody Boers didn't even allow them to get close enough to do fair rifle shootin'? And echo answered, "What?" Our M 1903 rifle had a bayonet installed only after much controversy, and then only because it could also be utilized as a cleaning rod. As a cleaning rod it was fairly efficient, as a bayonet it was a fair cleaning rod. However, before all the bayonets were beaten into pruning hooks and safety razors, the Japanese got into their Manchurian argument with Russia, and the bayonet hastily came back into its own.

The same optimistic attitude as to the capacities of the magazine rifle that nearly did away with the bayonet was also responsible for the abandonment of any other protection against modern bullets than Mother Earth. The big lead slugs of the 70's and 80's were entirely adequate to driving through the light armor of the cuirassiers; then the excessive penetration of the Krag and the Lee-Enfield; when these appeared, seemed definitely to put the quietus upon the armor side of the question. It is doubtful that even to-day armor would be revived as it has been, were it not for the many things of lighter penetration than bullets which are flying about our battlefields—shrapnel, shell splinters, grenade fragments, bayonet points. These things made light protection for the head very desirable; this, extended to the body in the form of a light cuirass affair, was then, because of the comparative immobility of the troops, thickened into protection against the bullets themselves, despite the weight thus added.

Glancing over the events of the recent war, therefore, we find a second coming of armor for man, gasoline horse and flying machine not equaled since the Middle Ages. The armored tank waddles imperturbably astride of machine-gun positions and cleans out the operators therein, it saunters down street in the face of cracking infantry fire. Armor coats the engines and most of the crew of airplanes, it surrounds light motor cars, it covers the head of every soldier of the fighting nations outside of Russia. It has been tentatively taken up as body covering in the form of layers of canvas and steel or of woven steel links. In thickness merely enough to stop the plain infantry bullet, it forms the

shield and the apron of every field gun. Most of these things, to be sure, are practicable only while the forces are in a state of relative deadlock; their weight would hamper troops on the march.

Our armored cars are reported to be covered with treated steel ¼-inch thick, which is sufficient to keep out the ordinary bullet. The armor of the field gun is ⅛-inch thick, and turns the service bullet at 100 yards. Our service bullet gets through a scant half-inch of mild steel. The special target-shooting pill makes the full half-inch; so does the German bullet. But against specially hardened armor steel any of these bullets might merely shatter, with no penetration worth speaking of. Knowing this, it was an easy matter to evolve armor and plates to keep the service bullet on the right side of the thing shot at. But at this stage of the game the projectile maker took a hand again, and once more the race was started between armor and projectile; and its ultimate outcome is as problematical as ever.



Courtesy of Scientific American.

Cartridges

Of the modern solid drawn brass variety.

BULLETS DESIGNED TO PLOW THROUGH STEEL

Special armor piercing bullets were not new when war broke out, but the occasion for them had been limited to getting through the shields of field artillery, and infantry didn't often get close enough to field guns to make this need an urgent one. But after the first year of the war, when snipers began to ensconce themselves behind armor shields and armored cars began to reinforce infantry at threatened points of the line, while airplanes demonstrated surprising immunity to machine gun fire, the ordnance experts began to take a keener interest in bullets that would not be so easily discouraged on meeting a stubborn steel plate.

The writer (Capt. Edward C. Crossman, whose articles appearing in the *Scientific American* have been freely employed in this volume) has had the privilege of testing several hundred rounds of ammunition loaded with the most successful armor piercing bullet yet evolved in this country, designed by Capt. W. L. Clay of our Ordnance Department, and made at Lowell, Mass., under the supervision of Captain Doe, formerly of our Army. This bullet (patent number 1202162), in common with most armor piercing bullets, uses the hardened steel core within a lead and cupro-nickel outer coating. It differs from any other bullet in that it is closed at the rear and filled from the front end of the jacket, giving higher penetration because of the lessened stripping tendency of jacket and lead. Also it has a softer nose than the tough cupro-nickel jacket. This enables it to bite on hardened steel surfaces very much inclined to its path instead of merely glancing off, as does the service bullet with its sharp nose and long shoulder.

This softer cap may be of lead alloy, copper, aluminum, or any other soft metal. In the case of the samples sent me for trial, it was merely soft lead. Inside is a hardened steel bullet in miniature, too hard even to file, and therefore resisting deformation on steel plates. In the samples it was left rather rounding at the forward end, so that enough of the leaden core would be driven forward, forming a cap to support the hard point and prevent it from shattering on the hard armor. In the bullet as finally redesigned, this point was made somewhat sharper.

The slug is .75-inch long and .218 caliber—the difference between this and .308, the diameter of the service bullet, being lead and jacket. The slug weighs 45 grains, the complete bullet 150, matching here the bullet of the service cartridge. Outwardly it is of the same form, but about 1/10-inch longer, to give service weight and of course to com-

© *Underwood and Underwood.*

The Place Where One "Big Bertha" Did Business

When the Germans were pushed back by the Allied forces in the closing months of the war, the artillery positions of the Germans were naturally captured. Among others was this huge carriage, discovered near Brecy, and undoubtedly intended for one of the medium-range German guns known as "Big Berthas."

pensate for the lower specific gravity of the steel core. It feeds readily through rifle or machine gun. The soft point on the sample makes it look precisely like the various soft-point bullets for sporting use of the Springfield.

The accuracy of the Clay bullet, while slightly below that of the service bullet, is higher than that of the regular French model, and ample for war use. At 200 yards it makes groups of about eight inches for ten shots, and at 1,000 yards it develops some ten per cent. of fliers, but not enough inaccuracy in the remainder to make its shooting inferior to the regular ammunition from a practical standpoint.

In mild steel, which as stated is no test of comparative effects, the Clay bullet got through an inch—a trifle above 100 per cent. more than the service bullet. Lengthening the range and using lighter plates gave an even more favorable comparison. Where falling off in velocity seemed to remove most of the wallop of the service bullet, the Clay armor-piercer continued to get through. At 700 yards against ⅜-inch boiler plate, which the service bullet merely dented, the Clay slug slipped through neatly.

© *Scientific American.*

Making Armor Plate

BULLETS THAT PERFORATE THE STEEL-SKINNED TANKS

On hardened steel, as near armor specifications as we could obtain, the effect of the piercer bullet was even more marked. At the muzzle it romped through ¼- to ⅜-inch

hardened steel, on which the service bullet merely spattered; at 400 yards it got through ¼-inch, though this was possibly not quite up to government quality. The trials demonstrated that the making of steel for this light armor is in itself a ticklish job. One piece, ¼-inch thick and glass hard, shattered to bits under the bullet's blow. On such steel as this the service bullet does not even offer to go through, merely putting a wide and very shallow dent in the plate; it gives just a blow, without drilling tendency. This is true even on the light 1/5-inch field-gun armor.

I am satisfied that at 500 yards the Clay bullet will get through the present shield and apron of our field gun, and that at 300 yards it would ruin our tanks with their ¼-inch protection. The light shrapnel helmet stops it at long range, and so does the airplane armor; but the bullet will go through the former at 2,000 yards and through the latter at 1,000. The British tanks are very heavily armored, and it is doubtful if even this type of bullet will go through.

The Germans were not behind us in the development of armor-killing projectiles. Before me lies a German piercer bullet from the Ypres salient, with which a sniper was killed through a quarter-inch of armor steel. This is a whale of a bullet, far too long to feed through the magazine of a rifle or machine gun without some change of parts. It consists of the usual hardened steel slug, leaden wall, and surrounding steel jacket; but the slug alone is as long over all as our complete service bullet, weighing 86 grains against the 45 of the Clay slug. It is very sharp pointed, although the taper is not long; and it is boat-shaped, having a tapering tail of only .20 inch. While it has hit steel, so that the lead core is nearly all missing, the fragments remaining weigh 147 grains, giving a mass somewhere around 200 grains for the finished bullet.

This elephantine piece of ammunition is without doubt a terrific drill for armor, probably much more so than the Clay bullet. But it has the serious drawback that it is not at all adapted to work with the regular ordnance, and its ballistics will be a thing apart, where the Clay bullet shoots to the sight graduations on our rifle and machine guns. It is apparently used in special rifles for snipers, resighted for it, or in special machine guns altered to handle the long cartridge—perhaps in both. Even though the infantry rifle were made to chamber it, it would not shoot to the sight markings, either the vertical ones or the lateral zero.

© *French Pictorial Service.*

Another Fragment of the German Shell

By carefully gathering all fragments and comparing them, the French were able to figure out the probable design of the German super-range shell.

The one general objection to all these armor piercing bullets is that, after completing penetration, they are reduced to tiny steel shot of .218 to .24 caliber; the remainder

of the bullet disappears into thin air on compact with the steel. The wounding power of a steel slug of such size and weighing but 46 grains is less than that of the familiar .22 long rifle, in spite of the advantage in velocity at the short ranges. But in spite of this, these bullets will greatly reduce the enthusiasm for steel bullet stoppers; even a .218 hole in one's anatomy is more discouraging than none at all.

HELMET AND GAUNTLET

How Heads Are Protected from Flying Metal, and Hands from the Omnipresent Barbed Wire

TRENCH warfare in France proved, among other unique characteristics, that the percentage of wounds in the head is considerably greater than in the pitched battles of former days. In a paper read before the Academy of Medicine of Paris, it was stated that 13.33 per cent. of all the wounds inflicted on the French troops fighting in the western theater of war were in the head, and head wounds of course are notoriously of a fatal character.

Moved by the large number of head injuries sustained by the soldiers in the trenches, the French Minister of War decided during the early months of the war to supply the fighters with metal helmets. After extensive experimenting at Bourges, France, with various types of head protectors, that suggested by a certain officer Adrian was adopted, the design of this steel helmet being such as to protect the head from shrapnel and ricocheting bullets more particularly. There followed almost immediately the work of manufacturing a sufficient number of helmets for all the soldiers at the front, and so smoothly and efficiently did the task progress that in a short time all French first-line troops wore them.

Although at a glance the steel helmets appear to be simple of manufacture, there are incurred no less than sixty-four separate and distinct steps before a complete helmet results. The first step consists of stamping out circles of sheet steel of .7 millimeter thickness. The punch press used for this purpose exerts a pressure of 150 tons on the cutting dies, and is under the control of the operator through the agency of a pedal. The capacity of the machine is 5,000 disks of steel per day.

The steel disks that have been produced in the first operation are then placed one by one in a pressing machine which forms each disk into a helmet with a broad rim. The partially formed headpieces are next sent through another pressing machine which completes this phase of the work by raising the helmet crown to the required height. The helmet crowns—the broad rim having disappeared in building up the crown to the necessary height—are then rotated one by one in a simple form of lathe and dressed with a cutting tool to remove all irregularities, followed by the polishing operation.

Meanwhile, the waste metal from the first step or punching out of the disks is being converted into brims on special shaping machines, each of which has a daily capacity of 12,000 pieces.

The next operation consists of punching the holes in the helmet crowns for ventilation purposes as well as for fastening on the crest, insignia and other accessories. The helmet crowns are held in a frame-work and all the holes punched at one time. This work accomplished, there comes the task of securing the metal brims to the helmet crowns. This is accomplished by soldering the parts together; a blow torch being used directly on the metal, instead of the customary soldering iron. Much time is thus saved.

At this point the helmets are virtually complete, lacking only the accessories such as the crest, the insignia of the arm by which each helmet is to be worn, the lining and the leather chin-straps. The crest and badge are attached

by means of eyelets, following which the helmets are thoroughly cleaned and dipped in a special mixture which dulls them so that they will not be conspicuous on the field of battle.

The last steps in the manufacturing of the head protectors are the insertion of the lining and the fastening of the leather chin-straps. The latter are attached to the helmets by eyelets; small punch presses being used to pierce the leather.

© Underwood and Underwood.

The Doughboy's Helmet in the Making

The so-called "tin hats" of our doughboys were turned out by the millions, at various stamping mills. Sheets of steel were punched into the rough shape in one punch press, and trimmed in another. The small humps shown in the corners of the untrimmed helmets were for the purpose of testing the sheets, before starting operations on them.

The steel helmet in use by the French soldiers is at once neat and highly efficient. Dr. Devraigne in studying the value of these head protectors examined 55 cases of head injury, in which 42 of the wounded men had no head piece and 13 wore helmets. Of the 42, 23 had their skull fractured, and most of them died. The other 19 had merely scalp wounds. Of the 13 men who wore the steel helmets, eight were suffering more or less severely from shock, but none died. The other five had slight superficial wounds or scratches.

Since Dr. Devraigne's investigation, the steel helmet has had ample opportunity to prove its worth—and it has not failed to do so. During the numerous offensive moves in France the helmets were much in evidence and, as a result, it is stated that the casualties were considerably less than they would otherwise have been.

In spite of the magnitude of the task of providing the French soldiers with metal helmets, five factories engaged solely in this work succeeded in turning out over 2,000,000 of these head protectors in six months' time.

They employed from five to six hundred men at various times and about 2,400 women. And after supplying the requirements of the French Army, these factories made similar helmets for the Italians, Serbians, and Rumanians.

THE "TIN HATS" OF OUR DOUGHBOYS

Our soldiers, like their comrades-in-arms and the common foe, were equipped with steel helmets while in the war zone. Our choice fell on the inverted soup-dish helmet of the British in preference to the French *casque* or the German coal-scuttle helmet. To the layman our helmet and the British helmet are identical; but if they are placed side by side and studied in detail it soon becomes evident that they are somewhat different. Still, the difference is mainly in the contour and the slope of the sides, and in the main the principle is the same. However, we were particularly fortunate in our steel selection; for penetration tests have proved our helmet to be superior to that of our British ally. Our helmets contain no cracks or flaws. In short, we have a helmet which, to all intents and purposes, is second to none in point of efficiency.

The manufacture of steel helmets is largely a matter of stamping and punching. And with our tremendous plants for stamping and punching anything from a small strip to motor truck bodies, we tackled the manufacture of millions of steel helmets without delay. From first to last the various steps in the manufacture of these helmets lend themselves most admirably to our American quantity-production methods; so much so, indeed, that the engineers charged with the work took keen delight in perfecting a system whereby thousands of them could be turned out every day with a minimum of labor. With some this work was a hobby.

The steel sheets for making our helmets were furnished to the various plants engaged in helmet manufacturing by the United States government. All cuttings and other wastage were returned to the government by the plants as a measure of war economy. Each sheet measured about a foot square by one-sixteenth of an inch thick when ready for the interesting manufacturing process.

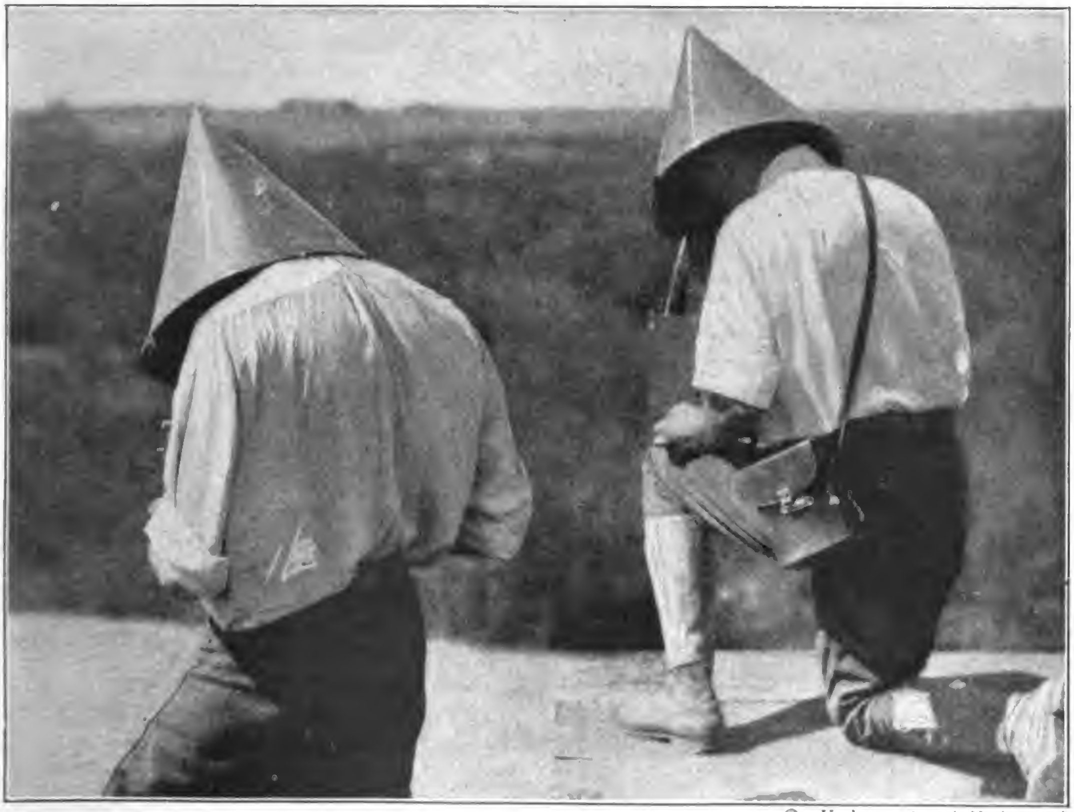
Now in theory every sheet is as good as the next, or at least it should be. But in practice this is not the case. One sheet out of every twenty-five, fifty or one hundred may have a hidden flaw which remains undetected until the sheet is subjected to the great pressure necessary to form the helmet. Then the flaw is detected and the helmet in the embryo state must be discarded. Not only is the sheet wasted in such a case, but all the manufacturing expenses up to that point must be charged against the defective steel.

American efficiency calls for a helmet from every piece of steel that starts through the plant. Hence the practice was to test each sheet before it found its way to the stamping presses. The test consisted merely of forming a small hump—in reality a small helmet—at each corner of the sheet; in other words, this was nothing more than subjecting a small section of the material to the same strain which the center section would have to bear in the huge forming presses. These small humps served to bring out any flaws that might exist in the sheet, and these were soon detected by inspectors who passed on the sheets.

Sheets with four perfect humps now made their way to the forming press. Each sheet was placed in turn between the male and female dies of a huge press. The operator manipulated a lever and the dies squeezed the sheet into shape to the accompaniment of an unearthly shriek. Covered with heavy oil, the sheet, now formed into the dome of the helmet but still carrying the square sides and humps in the corners, emerged an instant later from between the separated dies. Passing to another machine, each embryo helmet was placed between cutting dies which, at a single blow, cleaved off the four corners and the square sides and gave the helmet its ultimate shape. But the edge was not as smooth as it might have been, and another operation remained to finish the helmet proper. So it passed on to another section of the plant, where a steel binding or channel-section strip was placed round the rough edge. This was done by an operator who then pressed the helmet into a holder so that the binding was securely held in place with its two ends practically touching. Each helmet was then passed to another operator who welded the

steel ends together so as to form a solid ring or binding about the rim. For this work an electric spot welder was employed; each helmet was placed between the electrodes, and a slight pull on a lever brought the ends between the poles of an electric circuit. The welding operation was over in an instant, and the helmet was then removed from its holder. Provided with a smooth rim and in every other sense complete, it was now ready for the finishing touches.

The American helmet, like the helmets of other warring nations, was provided with a surface calculated to avoid reflection or glare on the battlefield. The French treated their helmets with a dull blue or brown paint, while the British covered their helmets with paint over which sand was sprinkled so as to break up reflection. In the case of our own helmet we made use of a material which served to break up reflection, but, at the same time, was a poor conductor of heat. This was a most important consideration; for we were told that British troops suffered not a little from the sun's rays striking on their sand-covered helmets during warm weather. Of course, canvas covers could have been used to shield the helmets; but it was preferable to make the helmet complete in itself.



© Underwood and Underwood.

Even Photographers Needed Steel Helmets

The picture man was not a fighter but he often risked his life in snapping battle scenes. For safety's sake he used the helmet while on duty near the front.

Obviously, the finishing of the helmet called for a head strap and the special lining. Like the British helmet, ours was provided with an inner frame separated from the steel covering by shock-absorbing members, so that bullets and blows were not communicated to the wearer. The completed helmet had excellent bullet-resisting powers; indeed, the tests were most exacting—and they should have been;

for after all, was not the stopping of bullets and shell splinters the *raison d'être* of the helmet? Yet the comfort of the wearer had been carefully considered. Consistent with the proper degree of safety, the helmet had been kept down to slightly over two pounds, ready to wear.

© Underwood and Underwood.

Armor for Soldiers

One protection against German rifle fire used by the Allies was the bullet-proof vest, weighing four and a half pounds and made of Government non-magnetic material.

A CLOTH WHICH IS PRICK-PROOF

One of the cruelest weapons in modern warfare is barbed wire. Hundreds of thousands of soldiers have paid with their lives in the encounter with that weapon of defense; and there is ample pictorial evidence of how storming troops, caught in the maze of barbed wire defending certain positions, have been mercilessly mowed down by the defenders. We have seen photographs of splendid Russian troops "hanged" on German barbed wire defenses—troops which, were it not for the wire entanglements, would have made short work of German infantrymen at close quarters. But until recently barbed wire had prevailed against all forms of attack except severe artillery preparation—and even then had given all sorts of difficulties.

A successful attempt to rob barbed wire of its terrors and potency was made by George Lynch, a traveler and war correspondent of London, England. Mr. Lynch invented a certain padded cloth which, it is claimed, is proof against the sharp points of barbed wire. In fact, with a pair of gauntlets made of this cloth, it is possible to handle barbed wire without the slightest fear of the spikes penetrating the material and scratching the hands. A convincing test of the peculiar properties is seen in a test where the wearer rested on a board studded with sharp nails, without sustaining the slightest injury.

Aside from gauntlets and gaiters, the new impenetrable cloth can be used for a number of other purposes. For instance, the cloth can be made up into vests, which, aside from affording protection against barbed wire, also insure the wearer against shrapnel splinters. Sleeping bags of the new material were also used by soldiers, protecting them from the elements in the usual way, with the additional advantage of being a protection against shell splinters and barbed wire. The sleeping bags when tied together can be thrown across an obstacle so as to afford safe passage to attacking troops. It is claimed that a blanket of the new material will bear the weight of a man's body without permitting the spikes to penetrate the material.

A 2-inch thickness of the special cloth will resist a Webley-Fosbery bullet fired at a distance of 25 yards. Indeed, such bullets as are not held up by the cloth are only permitted to pass with a certain amount of antiseptic wool, and the surgical value of this feature is at once apparent.

All in all, Mr. Lynch has done much to solve the barbed-wire problem, judging from

the extensive use of his cloth by most of the Allied armies.

THE RENAISSANCE OF BODY ARMOR

All sorts of body armor was employed during the war, as a protection against missiles of all kinds. Indeed, the curators of armor at the leading museums were freely consulted, and from the armor suits of past ages many invaluable suggestions were secured and applied to good stead in withstanding present-day forms of attack.

The Russians employed movable steel shields mounted on wheels, which were moved ahead of small bodies of men. These shields, being provided with loop holes, served to protect the Russian infantry against rifle and machine gun fire; but, and this is usually the shortcoming of such armor, it proved of no avail against shell fire. Being heavy and slow-moving, these shields proved an easy target for the German guns and thus sometimes became an actual disadvantage.

The Italians employed heavy body armor for the wire cutters—the volunteers who went ahead of the infantry in order to cut the enemy barbed wire and prepare the way for an attack. The French and British also employed armor, particularly for snipers and others engaged in desperate work. But it was the Germans, no doubt, who made the most extensive use of armor. Their storm troops were often provided with breastplates of heavy Krupp steel, which made these troops virtually immune to rifle fire and bayonet jabs.

In the United States we were hard at work on the armor problem when hostilities came to a close. Several museums were coöperating with the Army officials, and had we had the time, we would no doubt have developed something of real value in this direction. As it was, various private inventors came out with interesting forms of protection, among them a V-shaped armor which withstood a Springfield rifle shot at less than a hundred feet.

THE POILU'S HELMET

Interesting Tests With a French Helmet, to Determine Its Bullet-Resisting Powers at Short Ranges

IN the first year of the war, when the queer cap of the French poilu continued to grace his sunny brow instead of the present steel pot, a couple of quiet and business-like strangers appeared at the testing station of a huge American corporation making explosives, and asked if anyone there could test for them the bullet-resisting qualities of a steel helmet they had with them. The obliging assistant to the man in charge volunteered to do the testing. Trotting out a New Springfield, the American service rifle, and setting up the experimental helmet at a distance of 80 yards, he shot a neat round hole in the steel, through and through. The strangers smiled, thanked him, gathered up the perforated helmet and departed, first asking permission again to submit a helmet or so to his rifle. A few days later they returned with another helmet, and the assistant shot a hole in this one, likewise.

The strangers knew nothing about rifles or the effect thereof, they even expressed their surprise at the ability of the powder man to hit the helmet at such a distance.

But a third, and a fourth, and a fifth time they put in their appearance at the plant. By that time the powder man knew they were officials of a Philadelphia steel company of old and established reputation. Each time the brown service rifle obligingly shot a neat round deckle-edge hole in the helmet and each time the visitors gathered up the steel pot and went their way.

A HELMET WHICH KEEPS OUT BULLETS

Finally there came a helmet that merely dented where the bullet struck it. Two shots

had to land in the same spot to get through. It may be explained that the service rifle of our government has a striking energy of 2,430 foot-pounds, and a muzzle velocity of 2,700 feet per second, with a bullet in sharp point form weighing 150 grains. The next helmet—still of the light-weight steel necessary to keep the affair from telescoping the poor soldier's neck—refused to let the service bullet through. The powder man, with a quiet grin, trotted out a box of special match ammunition yclept "Palma," after the celebrated long range match for which it was loaded. This uses a bullet of 180 grains instead of 150, with the same muzzle velocity. At the muzzle it strikes a blow of 2,900 foot-pounds.

The big bullet merely shattered itself against the helmet, to the abject amazement of the powder man. This bullet, by the way, in the hands of the writer, has shot through half-inch plates of boiler-steel at the muzzle, and through quarter-inch plates at 500 yards. The helmet was merely rested against a head-sized rock to give natural conditions—not that the head of the poilu is akin to a rock, but this was the nearest approach possible with the limited equipment available. A second bullet, in practically the same place, still failed to get through. And at the range of 40 yards the experimenter smote the helmet again and again in nearly the same spot, until finally the eighth shot shattered the helmet into pieces at the point of the terrific pounding.

Each time of course the impact of the bullet drove helmet and rock through the air, and a solid support to the steel might have told a different story—but the helmet on the head of a man is not solidly supported. When the eighth Palma bullet finally shattered the helmet the pleased strangers carefully gathered up all the fragments and thanked the shooter and went away never to return.

Later, upon telling the officials of the Government Frankford Arsenal about the trial, the powder man met with laughter, jeers and contumely, the government men refusing to listen to such a yarn. The peeved powder man wrote the company making the helmets—or the steel therefor—asking for one to demonstrate to the government officials, but met with polite refusal.

The helmet tried out weighed as near as the experimenter could tell about six pounds, shaped like the helmets shown on French soldiers in the photographs from the front, and supported on the head by a light framework akin to the sun helmets worn in the tropics. Evidently the material was some alloy like tungsten, heat-treated, and not only hard, but tough. The shattering under the final blow indicated a glass-like hardness that was still devoid of the brittleness of most very hard and thin steel plates.

PROTECTION AGAINST BULLETS AS WELL AS SHRAPNEL

The writer, probably like most persons not on the inside, took it for granted that the helmet of the French and British was merely a protection against shrapnel, which has no great punch, and little penetration, being merely half-inch lead balls, traveling with the remaining velocity of the shell at its bursting point, plus about 200 feet per second imparted by the bursting charge within. As the shell itself has but 1,700 feet per second initial velocity, and probably not over 900 or 1,000 at the bursting point, the best laid shrapnel merely means a shower of round leaden balls with velocity not exceeding 1,200 feet per second, and probably nearer 800 as the average. With the scanty penetration of the round missile, this 170-grain leaden pill with its low velocity would be halted by almost any discouraging obstacle.

But a helmet that will resist the impact of a bullet of 180 grains, sharp pointed, .30-caliber, and traveling at 2,700 feet per second, is a different thing, more especially since care was taken, according to my informant, to make the impact of the bullet at right angles to the steel. A helmet capable of such resistance would nine times out of ten turn a bullet from the German rifle fired at a distance of 200 yards or more and do it without serious injury to the soldier because of the sloping form of the helmet, and the difficulty of getting a right-angled hit against the steel. The spitzer form of bullet is easily deflected against a sloping surface, more easily than the older form of blunt nose, the long shoulders sliding neatly off inclined surfaces which the blunt nose bullet, with more "biting" area to its point, would penetrate.

© Scientific American.

The Equipment of the French Soldier Showing the French Helmet

Equipment of the French infantrymen during the closing months of the war. The first trooper is an automatic rifleman, equipped with a Chauchat gun. The second trooper is a grenadier, equipped with hand and rifle grenades. The third trooper is a general utility man, who accompanies trench raiders. The fourth is an expert grenadier, while the fifth is a typical *poilu*.

The American doughboy's helmet was probably the best helmet in use. Indeed, in the manufacturing process particular pains were taken to see that the steel did not develop flaws in being pressed into shape. While of the same general design as the Tommy's helmet, it was considered a far better piece of work. As for bullet-resisting power, the American helmet turned away the regular rifle bullet at a reasonable distance, if it did not hit square. The regular test was to take helmets here and there from a big lot, and then fire at them from a distance of 10 yards with a .44-caliber Colt automatic. The hard-hitting bullet was supposed to flatten its nose against the steel sides, inflicting little damage upon the helmet itself, aside from making a dent.

HOW SHRAPNEL IS MADE

A Type of Shell Which Must be Built with the Accuracy of a Watch

THE first shrapnel shell, invented in 1784 by Lieut. Shrapnel, was merely a cast iron ball filled with bullets and powder, which was exploded by a crude fuse, screwed into the shell. This type was unsatisfactory, because bullets flew in all directions when the shell exploded. Later this defect was partially overcome by inserting a sheet iron diaphragm, which separated the bullets from the bursting charge. Modern shrapnel is similar in principle to its early predecessor.

A superficial examination of a shrapnel shell discloses little to indicate its destructive power —it is simply a small steel shell, attached to the end of a brass case, but when properly adjusted and fired from a modern field gun, this becomes a veritable demon of destruction. Within the brief period of 4¾ seconds it has traveled more than 1 mile, and 17¼ seconds later, it is nearly 3¾ miles distant from the gun.

A SHELL WHICH ACTS AS A GUN

Each shell has a time fuse that is made with the accuracy of a watch. This fuse is graduated in seconds, and is set to explode at a given range. As soon as the gun is fired, the fuse is ignited automatically, and when the explosion occurs in the base of the shell itself, the forward end is blown out and a shower of lead bullets hurled forward in conelike formation.

The velocity of these bullets exceeds the velocity of the shell at the time of the explosion by from 250 to 300 feet a second, and they cover a zone about 30 yards wide and 250 yards long, on an average.

All shrapnel used by different governments at the present time is made on the same principle, but varies somewhat as to size and in the arrangement of the fuse, which is composed of a slow-burning composition that is pressed into annular grooves. One of these grooves is in a stationary ring and the other in a graduated movable ring.

By turning the ring the length of this fuse is varied so that the shell may be exploded at any time within a period of about 21 seconds. During this brief period a 3-inch American shrapnel will travel about 6,500 yards, or nearly 3¾ miles.

Shells of the 3-inch size contain from 210 to 360 lead bullets, about one-half inch in diameter, which are embedded in a resinous mixture. This "matrix," as it is called, serves two purposes. It holds the bullets in position and also acts as a tracer to indicate by a cloud of smoke the point at which the shell explodes.

The interesting phases of shrapnel manufacture include the formation of the brass case, the forging of the shell, and the finishing of the various shell and fuse parts, to the degree of accuracy required. The making of a brass case 11½ inches long, 3⅜ inches in diameter, for the British 18-pounder requires seventeen different operations. It is formed from a flat circular blank 6¼ inches in diameter and ⅜ inch thick.

As these cases, as well as those for other kinds of ammunition, contain about 65 per

cent of copper, the importance of this metal in modern warfare is apparent.

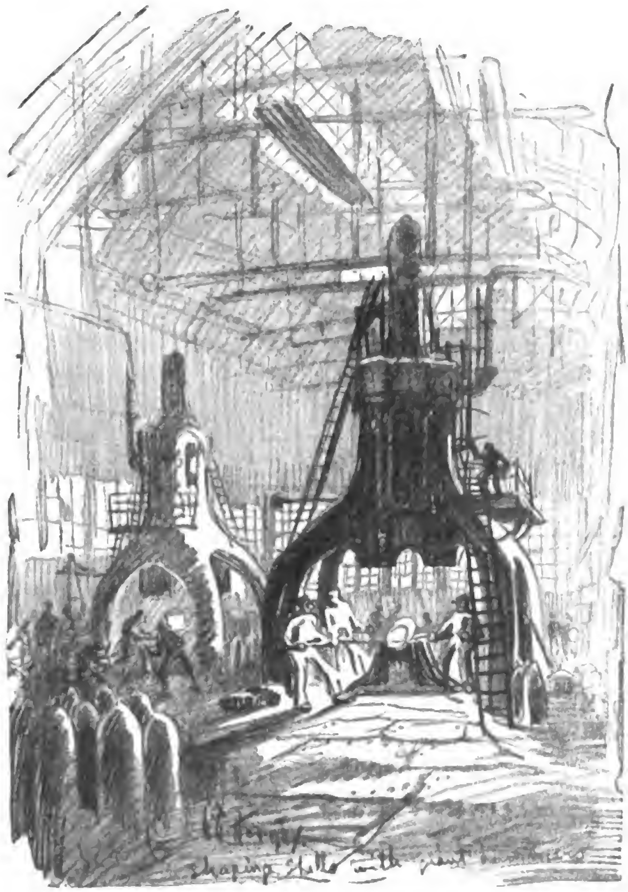
The shell is forged to approximately the required shape, either in a powerful hydraulic press, a power forging machine, or an ordinary power press, such as is used in sheet metal work. The presses used for forming these hollow shells from a solid billet are capable of exerting a pressure of close upon a million pounds.

For finishing the interior and exterior of a shrapnel shell many different designs of turning machines are in use. The tools are so arranged that one follows the other progressively, so that the drilling, turning, boring, forming and threading, are done rapidly and accurately. The exterior surface is finished smooth, and shaped to the proper size by a broad grinding wheel.

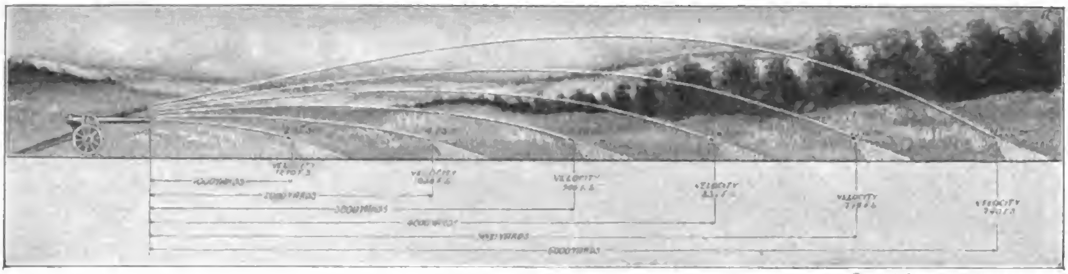
AN ASSEMBLY OF METAL AND CHEMICALS

The final step in shrapnel manufacturing is that of assembling the different parts. A charge of black powder is placed in the bottom of the shell. Over this charge is a steel disk or diaphragm, and then the remainder of the space is filled with shrapnel and the smoke-producing matrix. The time fuse is screwed in place at the forward end and covered with a soft metal case to protect the different parts. This outer case is not integrally a part of the shell, but is removed just before using the shrapnel.

It is important that the steel from which these shells are made have sufficient strength to prevent any bulging of the shell when it is subjected to the enormous pressure at the time of firing.



Forging Shells With a Giant Hammer



© Scientific American.

The Firing of Shrapnel

A field gun firing shrapnel, showing the trajectory and elapsed time for various ranges. It will be noted that the velocity of the shell drops very rapidly for every thousand yards of range. The maximum range of the usual field gun is about 6,000 yards, or roughly five miles.

An ingenious little instrument known as a scleroscope is used for making this strength test. This instrument has a small hammer, tipped with a diamond, which is allowed to drop from a fixed height upon whatever part of the shell is to be tested.

After this hammer strikes, it rebounds to a height depending upon the hardness of the steel, and as there is a definite relation between the hardness and strength, the graduated scale of the instrument indicates approximately what the strength is.

THE LIGHT THAT IS SHOT FROM A GUN

How the Great War Developed the Illuminating Projectile from Nothing to One of the Prime Requisites of Modern Fighting

OF all the strange developments of the war, none was more unlooked for on the Allied side, and none is in its very nature more surprising, than the fashion in which night was converted into day and the fighting put on a 24-hour basis. In all previous wars there has been some night fighting—but only when one of the contestants set out to surprise the other by falling upon him unawares in the dark hours. In the war of 1914-18, the trench deadlock which developed after the Marne retreat very soon reached a point where it was certain death for any one to show himself in the open during the hours of daylight; so that by a process of exclusion the fighting became localized and concentrated in the hours between sunset and sunrise.

This made the question of illumination a vital one. The side that attacks at night depends for success upon the cover of darkness, and if that cover be preserved, the attackers have at least good prospects, if not the actual advantage. Successful defense is then a matter of so breaking up the cover of darkness that night attack cannot be staged with good results.

Of course there is no intention or even desire to illuminate the night so that it will be like day. It is out of the question to have fixed lights where the enemy can see them and shoot at them. It might seem at first blush that this precludes the possibility of getting good illumination in the places and at the moments desired; but the artillery designer comes to the front with a device that saves the situation. This is the illuminating projectile—a shell or bomb or other device that bursts into flame at some point in its trajectory, and lasts for a longer or shorter interval. The idea is on its face one of great value, for it enables us to illuminate the enemy's positions and see just what he is up to while we keep our own in darkness; whereas

any other system of turning night temporarily or permanently into day would hardly work out so favorably to those employing it.

Germany, leader in the application of science to warfare, had long realized the turn which the war of the twentieth century was going to take, and the necessity which it would bring for the illuminating shell. She had carried on extensive research and development in this field for some years, so that when the first shot was fired she was well equipped with illuminating shell and illuminating bombs for use on the Western front. The Allies had nothing of the sort. England had done a little experimenting, but had not yet reached satisfactory conclusions, to say nothing of having disposed of the problems of production and transport and use.

This situation was serious. It gave complete control of No Man's Land at night to the enemy, who was free to undertake whatever enterprise he would, while secret movement of troops outside the trenches was impossible for the Allies. The ingenious Britishers made the most of a bad matter by inducing the Germans to supply them with such light as they had to have. That is to say, when they wanted illumination in a given neighborhood, they would manage to make a suspicious noise in that neighborhood, a noise that would suggest to the Boche that something was hatching there; and a flare of some sort would usually be forthcoming in the effort to stop the supposed attack. But this was a trifle uncertain, and of course could serve only as an amusing makeshift. The Allies got busy on the illuminating shell proposition, and eventually were on a parity with the Germans in this important feature of the war.

THE RIFLE LIGHT

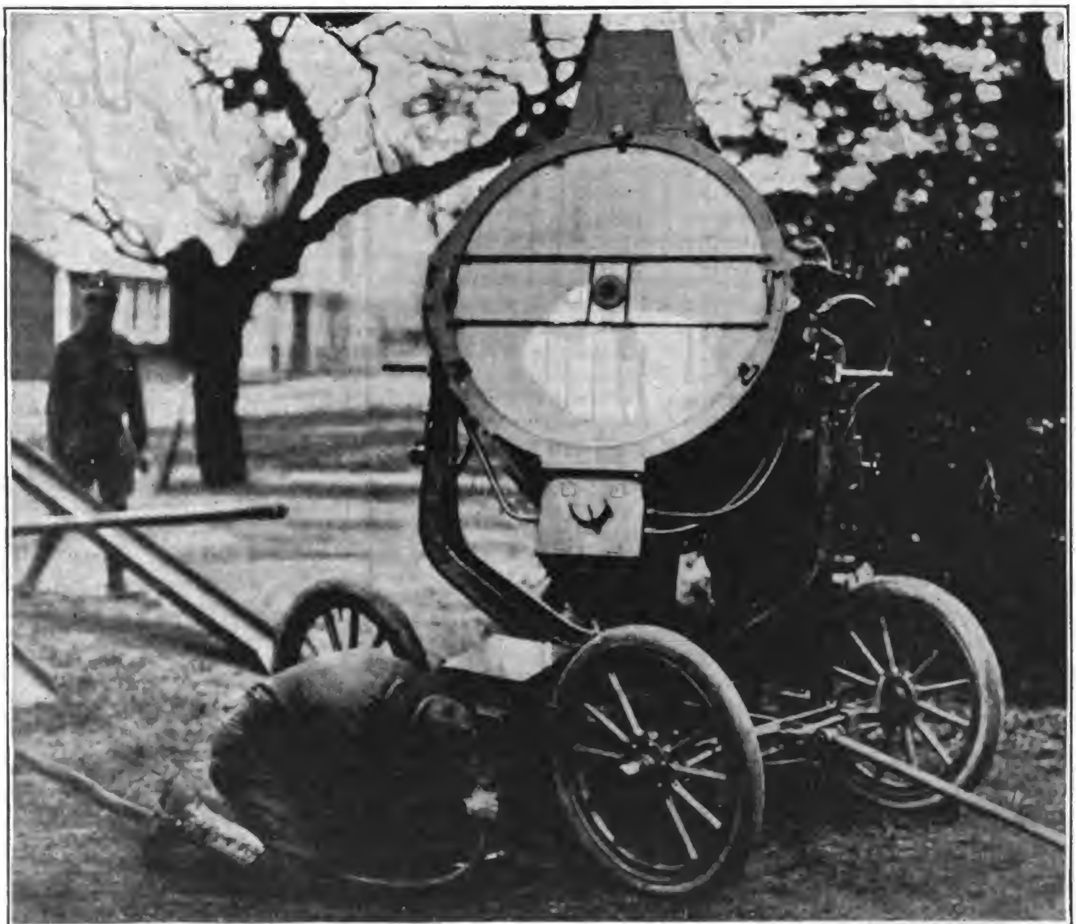
Illuminating ordnance may be divided into three general classes: rifle lights, illuminating drop-bombs, and illuminating shells. The rifle light is designed for short range illumination. In shape it resembles the ordinary rocket, being merely heavier and larger. As the name implies, it is fired from a rifle. It consists of a cylindrical steel container some six or eight inches long, mounted on a steel rod. Inside the container is a silk parachute and a cardboard case filled with the illuminating mixture. This mixture must be one that will not explode or be burned up too quickly, and it must not produce much smoke in its combustion. A priming mixture has usually to be added because it is difficult or impossible to find a good illuminant that will light readily or a primer that gives much light.

The rifle is loaded at the breech with a blank cartridge, and the rod of the contrivance just described is jammed down the muzzle as far as it will go. The rifle could be fired from the shoulder, but is ordinarily held at the desired angle by a block of wood and a frame. The firing of the cartridge gives sufficient powder pressure in the barrel to eject the light, though of course at a velocity not comparable with that of a bullet. The light is furnished with an inertia fuse, such that the "set-back" which the heavy outfit opposes to the forward acceleration brings the firing pin into contact with the primer cap, firing the latter. The principle is the same one that causes a person standing in a car to fall backward when the car starts suddenly.

The primer cap ignites a delay fuse, which burns slowly while the light is mounting to the apex of its trajectory, ordinarily quite sharp. If properly designed and fired, the fuse will burn through just at the moment when the highest point is attained. In addition to the illuminant, a separate small charge of black powder is then ignited, ejecting the parachute and cardboard container from the steel housing. The stem and steel container now fall freely to earth, leaving the burning illuminant to float down on the wings of the parachute as the latter opens under the pressure of the air. The light to be effective must be very intense. It should burn thirty seconds, but no longer—if it is not burned up at the end of that time there is waste, since it will hardly remain in the air and high enough to give good illumination for a longer period.

The rifle light is destructive of the rifle, because of its excessive weight when compared with the service bullet. Its range is of course very limited—at best it can cover only a few hundred yards. At this short range it is apt to give the enemy as much information as it does the side sending it up. The sender,

however, has the advantage of knowing where to look for the light and when; he can take cover when it is about to go up, and throw it over the exact spot which he wishes to observe. Moreover, if short illumination is sufficient for the purposes, the angle of fire and if necessary the propelling charge can be reduced, thus cutting down the time of flight. The rifle light, therefore, is of good service on the whole. It may not be out of order to remark that it was unknown before the late war, and therefore represents altogether a contribution of this particular war to military science.



Searchlights Which Converted Night Into Day

All armies entered the war with a full equipment of searchlights of the type here shown. This searchlight is carried on a motor truck, but can be wheeled about for a considerable distance. Electric current is furnished from a generator on the truck, through a pair of long flexible cables.

DROP LIGHT FOR THE AVIATOR

Just why a flare to be dropped from balloon or airplane is called a bomb might be rather difficult to explain. It is true that in shape and in manner of use it resembles a bomb, but the parallelism ends here. However, bomb it is termed and bomb we must call it.

The illuminating bomb is used either as an aid to the aviator who drops it, or as a mark for a distant range-finder who is counting on it to help him locate something in the line of enemy batteries. Its range of usefulness is a wide one. It is of the greatest value in

helping the aviator hit his mark with a real bomb, acting in this way much like the tracer bullet. It is simple in design and operation. It does not rotate and there is little inertia present. The problem resolves itself into the path of a body acted upon by several forces (gravity, the forward motion of the plane at the moment of release, and the action of the wind) and a study of illuminating mixtures.

Parachute, black powder to disrupt the container, primer and delay fuse must be employed much as in the rifle light. The new element here is that the bomb is dropped, not shot, so there can be no inertia fuse to start the train of events. Accordingly the aviator must do something when he drops the bomb which will ignite the primer and fire the fuse. This may be arranged to happen automatically, in connection with the release of the bomb, and this is best since the aviator should be called upon for as few specific, conscious acts as possible.

The bomb, as suggested above, does not fall vertically. It is not to be expected that the pilot can turn sharply every time a bomb is dropped, so in general the bomb will remain for some time directly beneath the machine. This means that care must be taken to have the delay fuse long enough, or the bomb may ignite close enough to the plane to do damage. This position of the bomb directly below the plane is not an unmitigated nuisance, however, for if there is one place where the aviator would rather have illumination than anywhere else it is usually directly beneath him. On the other hand, such an arrangement of flare and plane may give "Archie," as the anti-aircraft guns are called, just the line he needs to bring down the unwelcome visitor. So, like most other things, the natural course of events here works sometimes to the advantage of one side and again to that of the other.

THE STAR SHELL

The illuminating shell is by far the most important class of lighting devices. The more important variety from the point of view of range of utility is the so-called parachute type. This may be fired either from a gun or from a howitzer, according to the range desired. It comes in calibers ranging from three to six inches. All parachute star shells have much in common, both with one another and with the devices just described. A new complication, however, enters in that the shell must rotate. The parachute must accordingly be attached to its container by means of a swivel to keep its ropes from getting tangled. The empty body, after the shell bursts, does not fall at once but travels on for a distance. The illuminant must be very well ignited before the burst, or the sudden rush of air as the shell falls away from it will put it out. The design of the parachute is also a very delicate matter, since the forward velocity of the shell is far greater than that of the rifle light or the downward speed of the bomb; and the parachute must check its load without bringing it up so sharply that the fabric or the cords fail. The forces involved are difficult to calculate, and there is little more to be done about it than to build the parachute as strong as possible and launch it with a prayer. The shell of this type is made with a single star, or with such construction that it scatters its light over a wide area. Obviously intensity, duration and spread are opposed to one another and you must either sacrifice the ones that are not most important for the purpose in hand, or else make the best compromise possible between them.

The non-parachute illuminating shell is a special type designed for short, intense illumination only, finding its greatest field in defensive work against aeroplanes. Archie's crew know when and where the shell is to burst and are all set to take advantage of its brief flare; the pilot of the hostile plane is not thus prepared, and by the time he gets fixed so that he can see something by the sudden light, that light is gone. The design and operation of these shells need not be gone into in any detail other than to say that they are designed to burst in the air with a tremendous flash; but that since they do not float, and are filled with the quickest-burning materials available, this flash is but a momentary one. Of course, if you are looking for duration of light you will not select a shell that does not float in the air, hence the virtual restriction of this type to the purpose indicated. The non-parachute shell is always fitted with a time fuse, and you set it, with

knowledge of the shell's trajectory, so that it will bring the burst of illumination where you want it.

The chemicals used for the illuminating mixtures can truly be called the heart of the illuminating shell. The principal characteristics required are clear enough. The materials must be reasonably cheap and procurable in quantities. There must be none which are liable to explode or to ignite during manufacture, during loading into the shell, or during storage. The combination should keep indefinitely without loss of function. Ignition should be reasonably easy by aid of some of the standard priming substances. Either alone or when coated with some other substance it must pack when subjected to high pressure; and if coating is needed it must affect neither the ignition nor the luminosity.

All illuminating substances of a practical nature contain two elements, a fuel and an oxidizer. In no event may the designer rely upon the air to furnish the needed oxygen; for the mixture must burn when surrounded by a metal casing with combustion products present in quantity. The English run strongly toward magnesium as the fuel, with barium nitrate as the oxidizing agent. While aluminum is no substitute for magnesium on a basis of satisfactory service, the consideration of cost leads to its general use as an adulterant of the magnesium. Sulphur can be used, but hardly burns with the same ferocity as magnesium. The Germans, however, appear to have had difficulty in obtaining the magnesium, for they steered quite clear of it and employed a variety of other fuels, especially the sulphur and aluminum mentioned.

WAR'S DEADLIEST WEAPON

Describing the Machine Guns of the War, Which Took the Largest Toll of Casualties

TO go back to the origin of the machine gun it is necessary to go back through the centuries to the old Chinese gun, taken prize by the French in 1860, which now is reposing in the French Military Museum. This gun consisted of four iron barrels fired simultaneously, and it is believed to have been made earlier than 1300.

Since 1830, a breech loading battery, or, as it was then termed, "Organ Gun," has been in the Rotunda Museum at Woolwich. This gun consisted of rifle barrels in three parallel rows to the number of 31, which were loaded simultaneously by means of a set of chambers all fired at the same instant by a single cap. At the siege of Charlton, in 1863, one of these batteries was in use and did a considerable amount of damage.

The "Mitrailleuse," twenty-five to twenty-seven barrels hand operated, was kept as a great secret by the French until the Franco-Prussian War of 1870-71, but unfortunately it was used at long range as a piece of artillery by artillery gunners.

Then came two guns, both hand operated, the Gardner and Nordenfeldt; but it was not until 1883 that the first *automatic gun* was invented. This was made by Hiram Maxim. So good have the results been that the guns operated on this same Maxim principle are practically the same as the gun originally adopted by the British in 1889, and during the war were almost universally used by all other warring nations.

HOW THE GERMANS APPLIED THE LESSONS OF OTHER WARS

The Manchurian campaign showed the value of machine guns; both armies made frantic efforts to obtain these weapons before the war had been waging very long. Again, the Balkan wars showed the benefit of machine guns, the Turks making, on occasion, good use of them; but the Germans alone profited to any great extent by this experience. They bought enormous numbers of guns and trained their men in peace time to a very great state

of efficiency, the result being that they placed so much faith in these weapons that they had a corresponding fear of machine guns handled by their opponents and made every effort to locate them and knock them out.

A machine gun can do the same work as 100 men armed with rifles. That is, it can bring the same amount of fire to bear as 100 riflemen and will take up considerably less room. Consequently, it is possible to bring a tremendous fire to bear from a very restricted space—a sap head, corner of old trench, anywhere almost. Imagine a machine which is capable of doing the work of 100 men and requires a frontage of only about a yard, as a reserve power. To bring its equivalent, 100 men, across the "Tops" or through communication trenches takes time, causes obstruction of traffic, and is also conspicuous. In a crisis, or at a threatened point, machine guns are invaluable. The machine gun, being inanimate and mounted on a fixed tripod, is not affected by the excitement which is always present during action.

Germany from the start used a great number of machine guns, thereby saving a large number of men. A few men with a large number of machine guns can do the work better than a large number of men with rifles. In brief, it is simply the use of a "labor-and-man-saving machine" as an enemy-killer, and a man-saver by enabling commanders to have fewer men in the front and keeping more men in reserve ready for an emergency. The Germans trained men in a special separate organization, the Machine Gun Corps, gave them special pay, special uniform, and extra privileges. This unit was entirely separate from other branches of the service; consequently the information and experience gained in the employment of their arms at the very outbreak of war was quickly assimilated and used to advantage. Similar corps had been suggested by the British authorities, before the war, but this had been rejected on account of expense.

WHY THE MACHINE GUN WAS SOUGHT AND DESTROYED

Great efforts were made to prevent a machine gun carrying out its full powers by either side. The opposing commands did at no time hesitate to turn a battery of artillery upon anything that even looked like a machine gun or machine-gun emplacement, and, if necessary, shells of large caliber were used in the endeavor to knock it out.

At Hulluch, September, 1915, 9.2 and 12-inch guns were used on the troublesome machine-gun emplacements, and later it was necessary to send out the "Tanks" before it was possible to advance. If a battery can knock out 100 men it is worth while; therefore, they endeavored to knock out similar value by "strafing" the machine gun. When it is considered that one machine gun will hold up a battalion, and a few well wired in will hold up a division, the necessity of locating the enemy's guns and concealing your own must be apparent.

Machine guns are best used from innocent looking positions with good field of fire, such as hay cocks, behind timber, growing crops, bushes, hay ricks, bundles of sticks, etc.; that is to say, from positions which are not obviously placed where you would expect them. They are essentially weapons of opportunity and surprise. "Concealment is the best protection." In the northwest corner of the Grand Place, Ypres, there is a shell hole which measures 50 feet across the mouth of the crater and 22 feet deep in the center, caused by the arrival of a 42-centimeter shell (about 17½ inches) on a hard paved road. In another were buried thirty horses. This will show the folly of trying to build up anything strong enough to protect a machine gun from shelling. Of course emplacements are made to withstand small shells, shrapnel and bullets; but every inch put on will make an emplacement more conspicuous and any heightening above the line of a trench will be shelled, therefore one cannot repeat too often "Concealment rather than protection."

PLACING MACHINE GUNS TO DO THE GREATEST HARM

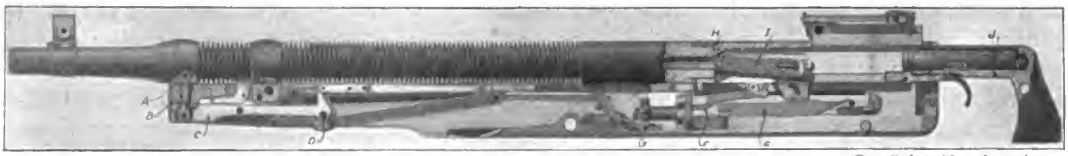
Machine guns produce a narrow, dense cone of fire, therefore they should be used to a flank, fired obliquely, and fired to the front only when a favorable target appears. A bullet from a machine gun will hit a man, and hit him again ten times as he is going down; but in the case of a gun catching men ob-

liquely you always have a target of fresh men. Machine gun training must play an important part in all new armies, and it is only the cool, reliable man with a thorough knowledge of his work and weapon that can get results. A man must know his gun as a keen motorist knows his car or a jockey his mount. The old idea that you wait for your enemy to show up in numbers, open fire, and then expect them to keep on coming, is wrong. Your work will be over in a matter of minutes and seconds and then you will have to move. On one occasion a machine gunner operating from second stories in village fighting changed his position six times, only firing five minutes from each place. In every case, inside of fifteen minutes from the time he had opened fire, the houses were shelled.

A rush of men may get past a gun, but not if it is enfilading a barbed wire or obstacles, and correctly handled. A gun in action enfilading 500 yards of wire is worth a man a yard.

PRINCIPAL TYPES OF MACHINE GUNS

Machine guns consist broadly of two types: the first in which the energy of the recoil of the barrel serves to operate the loading and firing mechanism, and the second in which this work is done by a small portion of the gases of explosion. To the former type belongs the Maxim gun. In this gun the barrel is enclosed in a breech casing, which is filled with water for cooling the barrel. The after portion of the barrel together with the firing mechanism is inclosed in a rectangular, oblong box, known as the breech casing. The gun barrel is carried at its ends in asbestos-packed bearings, within which it slides in recoil, the energy of recoil serving to operate the loading, firing and cartridge-case-ejecting mechanism located within the breech casing. The gun is held and trained by means of handles at the rear of the breech casing, and in front of the handles is a thumb piece by which the trigger is actuated. At the front of the breech casing is a recess which holds the feed-block through which is fed the belt of cartridges. The total recoil of the barrel is about one inch and the side plates and lock recoil with the barrel for a quarter of an inch, by which time the bullet has left the muzzle. The further movement of the barrel rotates a crank axle and opens the breech. The cartridges in the belt are fed forward by a step-by-step pawl action. It should be mentioned that a part of the energy of recoil serves to compress springs, whose energy in turn serves to operate part of the automatic mechanism concerned in the cycle of operations connected with the loading, firing, breech opening, cartridge case extraction, etc. To describe these movements in detail would take more space than can be devoted to the present article. The Maxim gun without its tripod weighs about 50 pounds. The disadvantage of weight is offset by the fact that in this gun the recoil is absorbed by springs and is not communicated directly to the operator, whereas in the lighter gas-operated machine guns, which weigh about 25 pounds without the tripod, the recoil acts directly on the shoulder of the operator, rendering it more difficult to keep the gun upon the target.



© *Scientific American.*

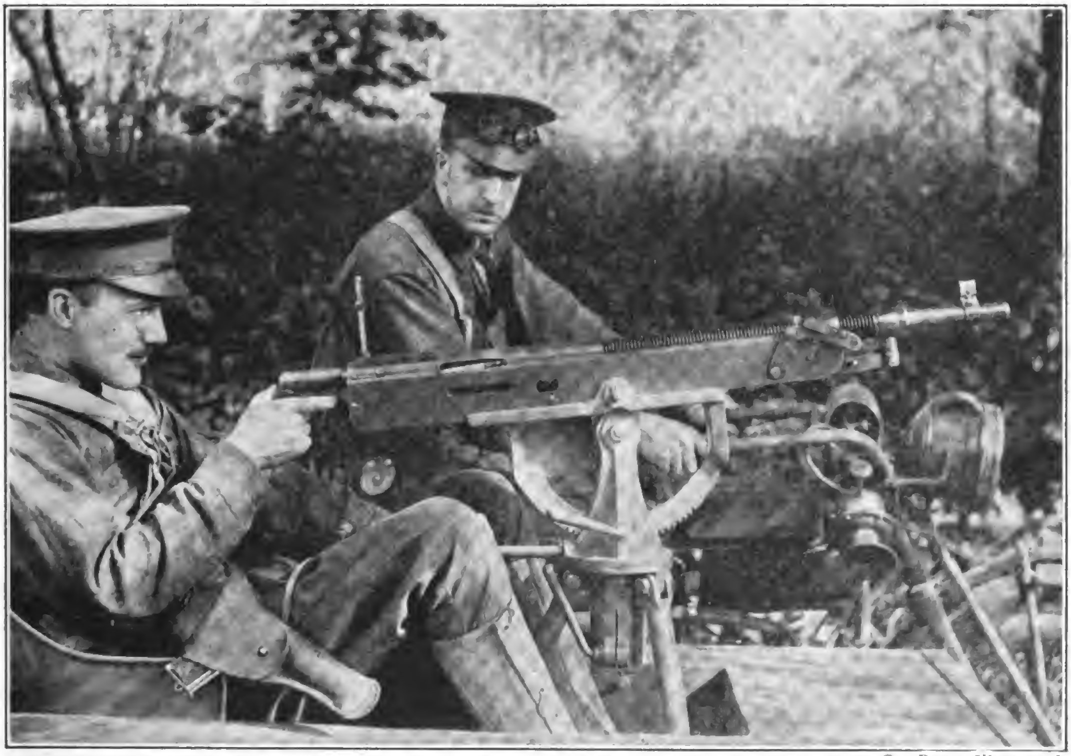
The Colt Machine Gun

Broken away to show the mechanism. Part of the gases of the cartridge are used to operate a piston at the forward end of the gun, and the piston in turn operates the gun mechanism.

The Benet-Mercier machine gun, as will be seen from our illustration, has no water jacket, a series of fins at the mid-length of the barrel serving to keep the latter cool during continuous firing. This gun is of the gas-operated type, the automatic devices being controlled by a portion of the gases of explosion and a spring located beneath the gun barrel. When the bullet has covered

about one half of its travel through the bore, a portion of the gases escapes through a gas nozzle, and acts upon a cup at the forward end of a hollow, cylindrical actuator, throwing it backwards toward the breech. This movement carries back the firing pin and turns the latter through part of a circle. This latter movement in turn acts upon the cartridge clip, bringing a new cartridge into position. Meanwhile the closing nut, which locks the breech, is rotated by means of a cam connection with the actuator, and this serves to unlock the breech-block, which is thereupon moved to the rear. An extractor then seizes the empty shell and ejects it from the gun. A new cartridge now drops into place. It will be noticed that within the actuator is a long spring, which during the rearward movement is compressed. The energy of the compressed spring serves to close the breech, lock it, and fire the new cartridge.

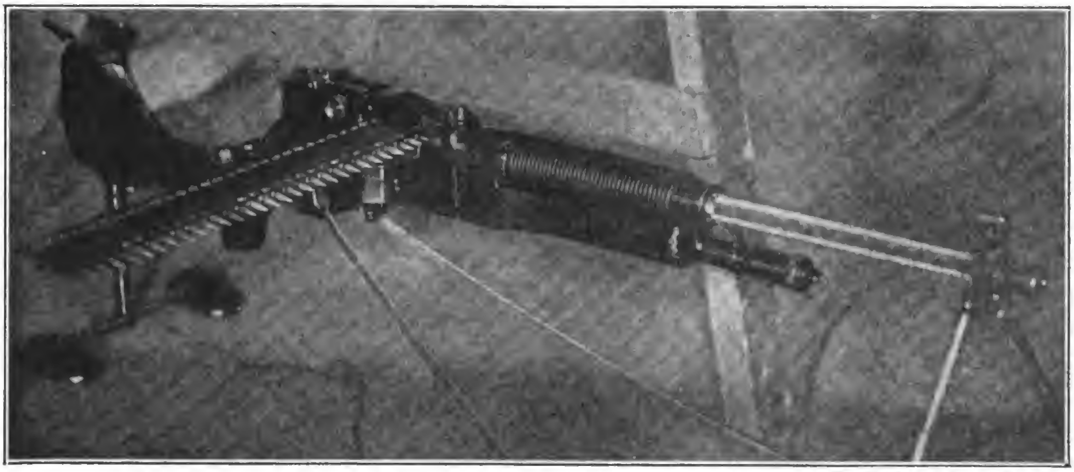
The latest gun to be adopted by the United States Army is the Lewis machine gun, which is also of the gas-operated type. In this gun a portion of the gases is admitted to a cylinder located beneath the gun barrel and drives the piston in the operating cylinder backward. This movement serves to perform the operations of ejecting the empty cartridge, inserting a fresh cartridge and placing the firing pin in position to fire another shot. The after part of the piston below the breech mechanism is provided with a rack which engages the toothed periphery of a case containing a coiled spring. The rearward movement of the piston partly winds this spring, which in unwinding closes the breech and returns the various parts to the firing position. The gun is supplied with ammunition from a rotating drum magazine holding 50 cartridges. A fresh magazine can be substituted in two seconds. The gun is cooled by means of a series of longitudinal ribs of aluminum fixed to the barrel, which are inclosed by a sheet metal case open at the rear and extending beyond the muzzle in the form of a con-



A Colt Machine Gun Mounted on the Side Car of a Motorcycle

tracted sleeve. The passage of the bullet through this sleeve induces a flow of air which carries off the heat of the burning.

Lewis guns are new weapons and are as distinct from machine guns as a revolver is distinct from a rifle, their only similarity being that they fire the same caliber ammunition. They are used by the infantry, and in the front line work they go over with the second and later waves. They are inconspicuous, can be carried easily, and look at a distance like rifles. The rate of fire is quicker and more concentrated than that of a machine gun. The 47 cartridges contained in a drum are fired at the rate of 780 a minute while the gun is firing; but it is impossible to maintain that rate of fire, time being lost through the drums having to be changed.



© Meden Photo Service.

One Type of U. S. Machine Gun

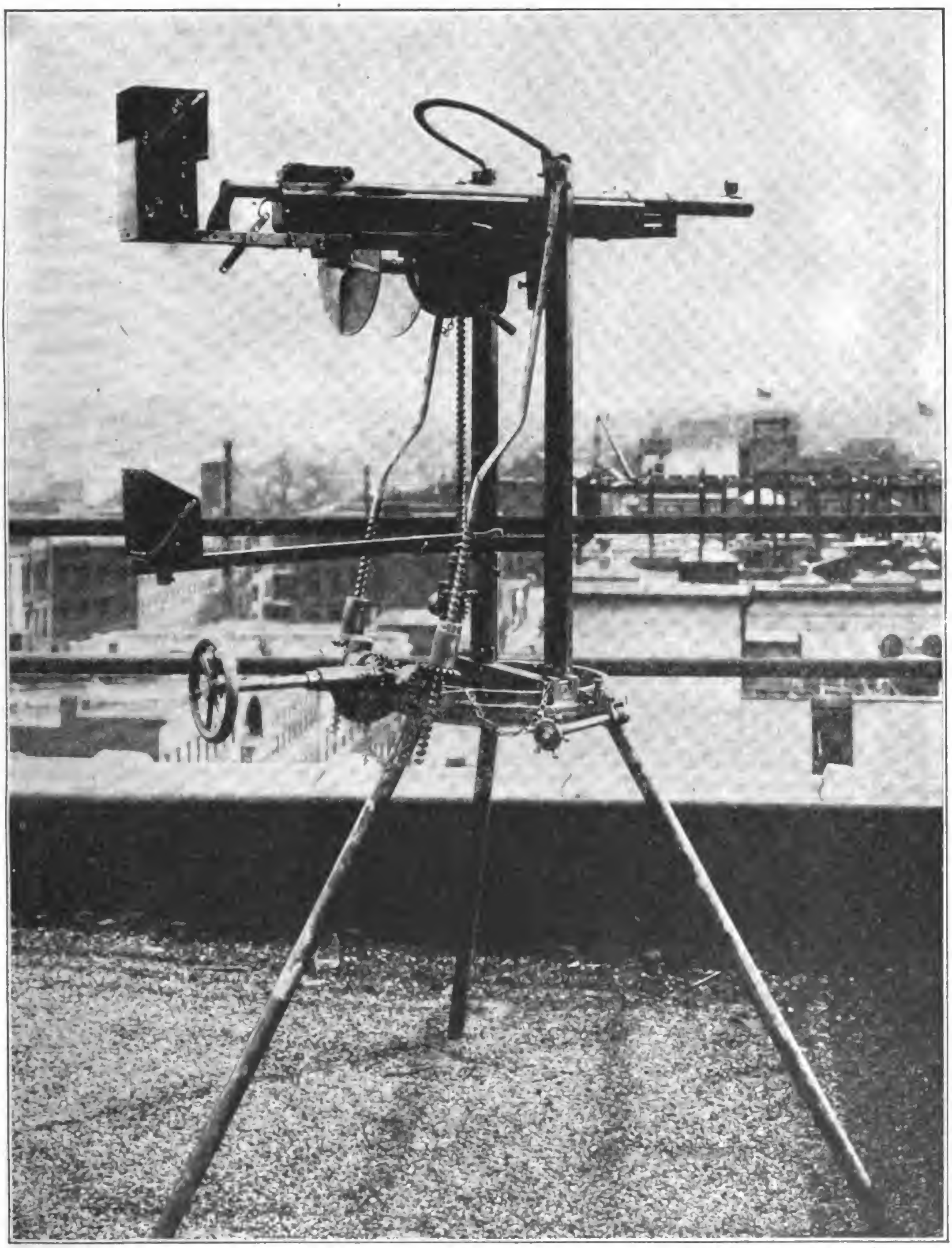
The Benet-Mercier, invented by a Frechman of that name. It fires four hundred shots a minute.

A GUN REFUSED BY OUR GOVERNMENT AND ACCEPTED BY THE ALLIES

This gun, which is the invention of an American officer, Colonel I. N. Lewis, was offered for test by the Army, and General Crozier submitted it to two tests at the Springfield Arsenal and rejected it. The enormous success of the gun after its adoption by all the Allied Powers aroused a feeling in America that here was yet another case of a rejection of a good American invention after it had been offered to the government. Hence, particular interest attaches to a field test (as distinguished from the shop tests instituted by General Crozier) which was ordered by Major General Wood and put through at Plattsburg. The test was carried out in connection with identical tests of the Benet-Mercier gun. The report of these tests, as published in the *Army and Navy Journal,* is as follows:

"In the tests, the loaded magazines were filled with wet and dry sand and were fired without cleaning, except removal of such sand as fell out when magazines were shaken. The Lewis gun fired the required number of shots in one minute and three seconds, while the Benet-Mercier guns fired only eight or ten shots in five minutes of firing and went out of action for the balance of the tests, having become jammed and unable to continue the tests. The Lewis gun immediately thereafter, fired 188 shots in fifty-three seconds, to demonstrate its functioning without the sand being removed from the gun.

"The most interesting test, however, was when the magazines of both guns were filled with thick mud, the guns remaining uncleaned after the sand test. The Lewis gun performed in forty-eight seconds, while the Benet-Mercier gun was unable to function after the sand test, and therefore did not even attempt to enter the mud tests. After the conclusion of these tests the Lewis guns fired



Courtesy of Scientific American.

A Colt Machine Gun

On a mount which enabled it to be used for anti-aircraft purposes.

twenty shots with deformed cartridges and battered shells in three seconds.

"The superiority of the Lewis gun in every other particular was clearly demonstrated, the following special advantages being noted:

"(1) Simplicity—this was especially important in the night work; (2) the comparative rapidity and ease with which a fresh magazine may be attached and removed in case of jam; (3) more efficient cooling device; (4) ease in cocking piece for first shot; (5) comparative ease in reduction of jams; (6) remarkably satisfactory action in mud and sand tests, and with deformed cartridges."

THE TWO BROWNING GUNS

And then there are the two Browning guns, which we developed during the war but which, unfortunately, were not available in sufficient numbers until after the armistice was signed. The Browning gun is practically a rifle, an automatic rifle, weighing 15 pounds, while the Browning machine gun is a machine gun very much along the lines of the Maxim in appearance, weighing but 34½ pounds. Both guns handle the same ammunition that the American forces in France used in their Springfields and modified Enfields, namely, the rimless .30-caliber, cupro-nickel jacketed cartridge, which develops a pressure of 50,000 pounds to the square inch at the moment of discharge. Thus the ammunition was interchangeable between all four weapons, which is an important consideration at the battle front.

Taking up first the light Browning gun, this weapon may be described as a rifle with automatic and semi-automatic action. That is to say, it can be employed for continuous fire, emptying its entire magazine in rapid order at the command of the trigger, or it can be employed as a self-loading and self-cocking rifle, in which case the rifleman pulls the trigger for each shot. In tests the gun has discharged its 20 rounds in 2½ seconds.

The Browning light gun or machine rifle, as it is designated by the Army officials, is

© *Central News.*

Novel German Machine Gun

This deadly weapon used by the Germans on the western front fired small shells with amazing rapidity.

of the air-cooled, gas-operated design. It may be fired from the shoulder, the rifleman finding his target over sights identical with those used on the new United States rifle, model of 1917, or from the hip, the rifleman finding his target by his general sense of direction, the latter being a knack quickly acquired through practice.

© Committee on Public Information.
© International Film Service.

Light Browning Machine Gun

This model was made to shoot from the shoulder.

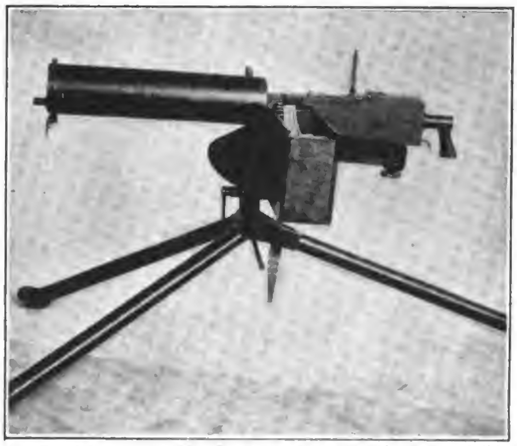
The principle of gas operation is simple. The gun is cocked with an easily operated handle for the first shot. The bullet is expelled by gases, which, as already stated, exert a maximum pressure of 50,000 pounds to the square inch. A small portion of this powder gas is taken off by the gun mechanism to act as power to operate the gun automatically. A bullet discharged from this gun has approximately the same energy as that fired from the United States rifle, model of 1917, or from the Springfield service rifle. Cartridges are fed from a detachable magazine containing 20, or for special purposes 40, service cartridges. The magazines may be detached by merely pressing a button and a new magazine attached by one motion, this changing operation requiring about two and a half seconds.

The gun may be operated as an automatic or as a semi-automatic arm by the manipulation of a conveniently-located lever. By putting the lever in the first position, the gun is made to fire single shots by trigger release; by putting the lever in the second position the gun becomes an automatic and will fire 20 shots in from two and a half to three seconds; the third lever position is the "safe" or locking device. It is said by the military authorities that the designer intended the gun to be used more as a semi-automatic than as an automatic arm.

GIVING THE GUN A REST SO THAT IT MAY COOL OFF

Powder gases create terrific heat, sometimes developing the destructive temperature of 4,000 degrees Fahrenheit. An air-cooled automatic gun, therefore, has its limitations. The Browning rifle has an open and very simple construction and cools remarkably quickly. The rifleman may fire 350 continuous shots from it without having to stop to cool the weapon.

The chief characteristic of the gun is its extreme simplicity of construction, rendering the manufacturing problem correspondingly simple. It has fewer than twenty principal parts and possesses the great advantage of standardization, being easily and quickly taken apart and reassembled by the ordinary soldier. From the manufacturing viewpoint, the gun possesses the great advantage that it may be promptly produced in large and increasing volume as shop machinery is multiplied and operating personnel developed.



© Committee on Public Information.
© International Film Service.

Heavy Browning Machine Gun

This model was used for heavy-duty work—such as defense

Used cartridges are ejected from the side of the gun, never crossing the sight of the rifleman, and coming out with sufficient force to clear themselves beyond his notice. A feature of the rifle is that the cocking handle remains stationary when the gun is in operation and is so arranged that it will in no way

hamper the gunner, thus eliminating a danger common to many guns.

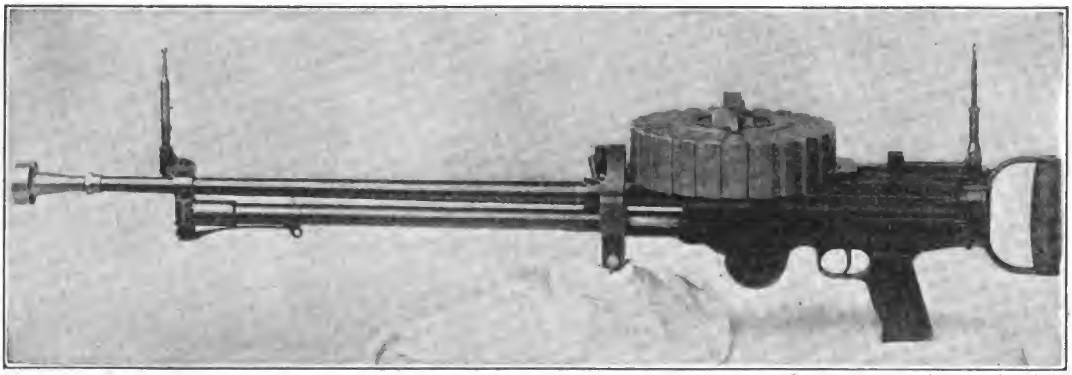
The gunner may operate the gun at all times without aid. Only one tool, a small wrench, is needed to care for the gun, as most of the operations of taking it down and reassembling may be performed by use of a cartridge as a tool.

As the gun is intended for the use of charging infantry, the problem of ammunition is naturally an important one. In this connection we are told that the gunner carries approximately 120 rounds of ammunition in his belt or bandolier and his two assistants carry 400 and 240 rounds, respectively, loaded in magazines. The loaded magazine weighs twenty-three ounces. Thus it is possible for a gunner to go into battle with a supply of about 800 rounds of ammunition.

Equally interesting is the heavy Browning gun, which is of the water-cooled, belt-feed design, and is operated by means of the power created by the recoil action. It is fed from a cotton belt which contains 250 rounds of service cartridges. The belts may be rapidly loaded by means of a machine which is a development of the one which Mr. Browning devised some twenty years ago in connection with the Colt gun.

Like the light gun, the heavy-duty Browning piece is marked for its simplicity of construction, rendering manufacturing problems easy and giving it a high degree of endurance. In the government test 20,000 rounds were fired from this gun with only three stoppages, one being due to a defective cartridge. In a further test firing was continued with the same gun to 39,500 shots, when the gear gave way. A duplicate gun fired 20,000 shots in 48 minutes 16 seconds without a malfunction, and with only three stoppages, these being due to defective cartridges.

The light weight but sturdy tripod of the Browning heavy gun permits the ready laying of the gun on its target. The cartridge belt is held in a wooden box fastening on the left side of the gun, as in the case of the Colt machine gun; this and the pistol grip of the new gun are reminders of the earlier gun of Mr. Browning's conception. This same gun, with certain modifications including the stripping of its water jacket, weighs but 22½ pounds and should prove satisfactory for aviation service.



© International Film Service.

Lewis Gun for Airplane Use

This type was used by the British and French airmen. The high speed of air machines made the use of a radiator on the barrel unnecessary.

MACHINE GUNS THAT ARE CARRIED ON AIRPLANES

The Browning gun has successfully undergone a test to determine its value for use with aircraft. This is one of three types of machine guns with which the rate of fire can be so synchronized with the revolutions of the propeller of a tractor airplane that the gun can be fired by the pilot of a combat plane through the revolving blades. Firing in that fashion, it is necessary to aim the machine gun by steering the plane directly at the target. The direction of the plane gives direction to the fire and the pilot can fire

the machine gun while controlling the plane.

Airplane propellers revolve at from 800 to 2,000 revolutions per minute. The machine gun is connected with the airplane engine by a mechanical or hydraulic device, and impulses from the crank shaft are transmitted to the machine gun. The rate of fire of the machine gun is constant and its fire is synchronized with the revolving propeller blades by "wasting" a certain percentage of the impulses it receives from the airplane engine and by having the remaining impulses trip or pull the trigger so that the gun fires just at the fraction of the second when the propeller blades are clear of the line of fire.

The pilot operates the gun by means of a lever which controls the circuit and allows the impulses to trip the trigger.

The test given the Browning gun was severe. A gun was mounted on the frame of an American combat plane and connected with the airplane engine. The test was conducted on ground and in place of the propeller a metal disk was attached to the crank shaft. The Browning gun was then required to register hits on the metal disk as it revolved at various speeds from 400 to 2,000 revolutions per minute. The slightest "hang fire" or delay in action on the part of the gun would have been shown by the failure of the bullets to hit precisely in the spot on the disk representing the center of the cone of fire. The gun functioned perfectly.

The Browning gun to be used with aircraft is the heavy type with the water jacket removed. Besides the Browning, the United States likewise employed the Marlin aircraft gun as a synchronized weapon. Several thousand of these were manufactured and the gun was on a basis of quantity production.

There was much doubt and some open criticism of the American action in adopting the untried Browning in the place of some gun that had made good in actual conflict. Many people feared that the United States was taking too extreme an attitude of being able, without half trying, to produce an article better than what any other nations could turn out after long experience. The fact was that the Browning arm was designed with equal reference to service and to production; it was the one model that our factories would be able to turn out in huge quantities—and the best is bad if it can not be made available for use.

The British and French use the Vickers as a synchronized machine gun. The Lewis aircraft machine gun is used by the British, French, and American forces, but for a different purpose. In a two-seater combat plane fixed machine guns are mounted forward to be operated by the pilot, and flexible guns are mounted to be operated by the observer in the rear seat of the plane. The observer operates Lewis guns on flexible mounts, firing to right or left of the plane.

It is of vital importance to have absolute reliability of function in a synchronized machine gun on tractor airplanes. Delays in fire or malfunctions due to faulty construction or imperfect ammunition cause bullets to strike the propeller blades. As many as 15 bullets have been known to strike the propeller blade without causing an airplane to fall, but the danger of such occurrences is nevertheless obvious. Only specially selected ammunition is used.

The two Browning guns have been proclaimed excellent types of machine gun and automatic rifle, respectively. Unfortunately, the war ended before they could receive a thorough test in actual battle. But as far as convincing tests are concerned, the guns have produced a most favorable impression. Furthermore, their design reflects the years of experience of the inventor in firearms of all kinds. As a quantity-production problem, moreover, both guns are ideal in every respect, permitting the maximum employment of automatic machinery, interchangeable parts, rapid assembly, and all those other features which go to make tremendous production possible.

The Germans and the Austrians employed a modified type of Maxim for both their heavy and light machine guns. In all fairness it must be admitted that both these major enemies had excellent machine guns, and knew how to handle them.

The French made use of the Hotchkiss type which at the beginning of the war they served with clips of 25 or 30 cartridges, while later they resorted to belt feed, following the practice of the Germans, Austrians, Italians, British, Belgians, and all the other fighting powers, for that matter.

SELF-LOADING MILITARY RIFLE

Guns Which Operate Their Own Breech Mechanism and How They Do It

DURING his continuous performance of the long four years of war, old grim-visaged Mars has demonstrated at once the great desirability of a self-loading infantry rifle, and the great difficulty of filling an order for a satisfactory one.

Unfortunate was the emergency that compelled this country hastily to recommence the manufacture of our New Springfield, and to adopt a supplement therefor, a modified version of the British Enfield Model 1914, which is merely the Springfield in the principal points thereof. The fighting during the World War had shown the urgent necessity for an infantry rifle that would give as near as possible to machine gun speed of fire. Small arms firing regulations of both our own and the British armies have been modified to lay stress on the importance of rapid fire, real rapid fire, not the rather leisurely procedure that has masqueraded as rapid fire in our firing courses—for instance, ten shots in one and a half minutes.

British army men have written that the best remedy for the attempt of Fritz to come over and visit with them in their own fire trench was 15 rounds rapid, which means 15 rounds in one minute. This rate utilizes to about full capacity the rapid fire possibility of the hand-operated rifle, although skilled men have fired 25 and 30 aimed shots per minute in special test.

The change in army procedure shows plainly the necessity for a high rate of fire with accuracy, and this in turn indicates plainly the self-loading rifle as the rifle par excellence. Such a weapon permits of a much higher fire rate, does not disturb the aim in bolt manipulation, does not expose the manipulating hand and arm and puts all men on the same basis of rapidity if not accuracy in that the painfully acquired technique of working the bolt rapidly is not at all necessary.

In days gone by, when fighting was at greater range and the infantry didn't burrow into the ground at the slightest pretext for a halt, the difficulty of fire control lay in making the men fire slowly enough. At all but the close ranges of the so-called "normal attack," the rate of fire was two shots per minute. A rate higher than this was held incompatible with accuracy and coolness of fire and ammunition conservation. Now the faster the soldier can fire and still remain accurate, the better, merely because the ranges are usually short, the speed of the attackers great, and the time in which to break up the charge uncomfortably short.

Light machine guns, re-baptized automatic rifles to differentiate them from the heavier type machine guns, are carried by a given number of men in each company, forming a machine gun platoon. To give every infantryman an automatic rifle of this sort would make the fire still more effective, but obviously, because of the question of ammunition supply and of the weight of the arm itself, this is out of the question.

HOW THE SELF-LOADER DIFFERS FROM THE MACHINE GUN

The next best thing is the rifle that does all the work of breech manipulation by virtue of the energy of recoil or by gases taken from the barrel, leaving to the soldier firing it only the work of pulling the trigger for each shot. The speed of fire of such rifles—sold in sporting form over the counter of all sporting goods stores—is limited to the rapidity with which the firer can twitch his trigger finger, up to the limit of the capacity of the magazine. They differ in principle from the true machine gun only in that the trigger must be pulled for each shot, and of course in the absence of the cooling and magazine features of the machine gun or automatic rifle.

Every civilized nation has experimented with military rifles of this type. No rifle came up to the scratch in pre-war days in all the points of simplicity, endurance and reliability. Now the demands on the rifle in the way of ease of cleaning and care and immunity to abuse and mud and grit are greater than in the days before the war. The need for the self-loading rifle is shown more plainly than ever—and the satisfactory rifle to fill the need seems farther away than ever, in spite of the keen efforts to meet the demand.

Rifles that do the work of breech manipulation are divided roughly into two classes—the recoil operated and the gas operated. Machine guns follow the same classification, and are about evenly divided in actual number now in operation. The Maxim, the standard German machine gun, is recoil operated. The Benet-Mercier, the Lewis and the Colt are gas operated.

RECOIL OPERATED RIFLE

The sporting rifles sold to hunters are confined strictly to the recoil operated type, the list taking in the Remington, the Winchester and the little known Sjogren of England. The designer of the recoil-operated, self-loading—often miscalled automatic—rifle is confronted with the difficult task of both locking his rifle firmly against the thrust of the cartridge in the chamber, and yet utilizing that push to operate the mechanism of the rifle. If it is permitted merely to oppose a heavy unlocked bolt and a powerful spring to the backward push of the cartridge, then the task is easy, and we get what is called the "blow-back" type of weapon, a type including the familiar and successful Winchester self-loading rifles and various automatic pistols. In this type there exists a necessarily delicate balance between backward thrust of the cartridge case in the chamber, and the weight of the bolt and push of the main spring or retractor spring behind it. If the bolt and spring offer adequate resistance then the speed of recoiling parts will be too great and there will be an escape of powder gas at the breech, not to mention the probability of blowing the cartridge case in half because the back portion would try to back out under gas pressure, while the forward and thinner one remained glued to the chamber walls by the same lateral powder pressure.

If the bolt and spring offer too much resistance, then the rifle will merely not function. Any overload or any serious obstruction in the bore, tending to raise the chamber pressure, would destroy this balance and so the refusal of military boards to countenance this type of action. However, it works nicely in arms of the sporting sort.

While necessitating a clumsy barrel cover, the Browning plan of recoil-operated rifle is thus far the most practical and one much copied by "designers" of foreign rifles of the military automatic type.

In the Browning plan, used in the Remington big-game series of self-loaders, the recoil of the fired cartridge drives backward the breech bolt and the barrel, firmly locked together, the barrel sliding in guides provided therefor. The backward motion compresses the retractor and main springs. At the end of the travel, which is about the length of a cartridge, a trip releases the lock between bolt and barrel, the heavy retractor spring drives the barrel forward to position again, ejecting the fired case, while the breech bolt is momentarily held back. A fresh cartridge rises into the path of the bolt, which then flies forward, carrying the new cartridge into the chamber, and locks itself by the turning of the bolt head into locking shoulders, as with the Mauser hand operated rifle. Here the delaying action of barrel and bolt sliding together serves both to prevent the undesirable unlocking of breech bolt while powder pressure is in the chamber, and to compress the requisite springs to carry out the reloading and closing sequence of actions.

In the Sjogren there is a heavy unlocking bolt on the breech bolt proper, arranged to slide freely in a line with the bore. On discharge the sliding bolt remains stationary, the rifle sliding beneath it until, at the end of the travel, the bolt unlocks the breech bolt proper which then opens under the reduced powder pressure and operates like the bolt of a straight blow-back rifle—sliding backward, ejecting the fired case, cocking the striker, compressing the retractor spring, and finally closing again on a fresh cartridge fed up from the magazine. Here the sliding unlocking bolt serves merely to delay the unlocking of

the breech bolt until the powder pressure is off the head thereof.

THE FORWARD-MOVING BARREL

A third application of the recoil operated principle is the forward-moving barrel idea, seen in the Swartzlose automatic pistol, sold in this country prior to the war. Here the "drag" of the bullet against the light barrel is alleged to force the barrel forward to the limit of its travel, compressing the retractor spring and cocking the arm, whereupon the barrel backs into place on a fresh cartridge that rises in front of the bolt and the arm is closed for firing. As a matter of fact the pistol in part backs away from the barrel much as the Sjorgen rifle backs away from the sliding locking bolt. This is proved by the fact that if the firing hand is placed against a wall and the trigger is pulled, the gun will not function; the backward jump of the pistol has really more to do with the functioning of the gun than the actual forward motion of the barrel.

A highly successful automatic military rifle, invented by Sir Charles Ross, of Canadian Ross fame, and operating on the forward moving barrel principle, has been submitted in various forms to the Ordnance Department, and evidently contained much that had merit inasmuch as the arm has been altered to conform more to their demands. While there is not the slightest disposition on the part of the barrel of a gun to move forward when a cartridge is fired in its chamber, there is much willingness on the part of the rest of the rifle to recoil back away from the barrel if the latter is not firmly connected to the arm, and so it is entirely possible to make a rifle function by having the barrel stand still in its guides and let the rest of the arm recoil away from it. The effect is that the barrel slides forward—as would be the operation were the gun loaded by hand.

GAS-OPERATED RIFLES

All devices depending on recoil, however, are more or less clumsy and complicated compared to the simple plan of taking a little gas from the barrel and using it to operate a gas-engine type of miniature piston in its cylinder below the barrel. This is the operating principle of the Benet-Mercier and Lewis guns. The Colt uses gas, but lets it impinge on a lever hinged below the barrel and working downward through a portion of a circle on its hinge.

This principle is purely the utilization of a miniature gas engine, deriving its charge from the gas behind the bullet. The small portion "borrowed" has no effect on the ballistics of the arm. Such gas operation permits the use of the bolt of military type. The operation of the rifle cannot commence until the bullet passes the port well up the barrel and that means that its exit into the air is then a matter of time almost too short to measure.

General Mondragon of Mexico designed a rifle on precisely this principle for the Mexican Army just prior to the Madero revolution, and a number of such rifles were made. He used the backward drive of the piston to revolve a military type of bolt through an eighth turn as a soldier would do by hand, freeing the lugs from their engagement with the shoulders in the receiver and driving the bolt to the rear. This gas-borrowing principle is also used on the experimental British Laird Mentyene Degaille rifle, the Farquhar-Hill rifle of converted Lee-Enfield type and on various experimental rifles built by our own arsenals for experiment prior to the war.

The objection to the gas-operated type of rifle is the slight tendency for the working parts to corrode from the gas used to move them, and the slightly greater difficulty in keeping the bore clean, due to the creeping up of corrosion from the unreachable gas-port in the barrel. Care can prevent this trouble.

REQUIREMENTS OF THE SELF-LOADING MILITARY RIFLE

The successful self-loading military rifle should operate in three distinct ways. The first, the ordinary hand operation of bolt, to be used for slow fire at long ranges to prevent waste of ammunition. The second, the semi-automatic functioning in which the breech bolt opens under gas pressure but is closed by hand by the soldier or else allowed by the soldier to close under spring pressure at the touch of a catch. This also slows down the fire rate and aids control. The last

is of course the straight "automatic" function of the rifle for rapid fire, in machine-gun fashion save that the trigger must be pulled for each shot.

Any such rifle could be easily converted to straight machine gun automatic fire by installing a cam bolt to turn down the sear out of the path of the firing pin and let it return against the primer each shot; but with the light weight of the rifle the rapid sequence of shots would "bounce" it all over the place and the limited magazine capacity would make this sort of fire—400 to 600 shots per minute—entirely useless in that it would empty itself in a second or so. Many an incautious experimenter with self-loading sporting rifles has got the trigger mechanism out of order, and had the rifle remark, "Pra-a-a-a-p," with the entire magazine the first time he pulled the trigger. It is an experience more surprising than pleasing.

The ideal rifle of this self-loading type would permit the simple manipulation of the bolt by the soldier for slow fire without compressing each time the powerful retractor spring, which is somewhat of an effort and which would make the manipulation of the rifle even slower than was desired.

Practically any rifle of this type can be fired at an astonishing rate of speed. Five shots can be fired in two seconds without trouble, a 20-shot magazine can be emptied in as many seconds with fair accuracy. Wherefore the self-loading military rifle, to permit the utilization of its rate of fire, must have ample magazine capacity—not less than 15 rounds, preferably 20 or 25, clumsy as it might make the arm.

At a reasonable estimate the fire of a given number of men with such weapons and large magazine capacity would be equal to the fire of three to four times their number armed with the present type of hand-operated rifle, if the occasion was stopping a rush by a close-at-hand enemy.

But the speed of fire and consistent working are, alas, not all that are necessary for the successful rifle. It must be capable of being quickly taken apart for cleaning and the reduction of jams, must have few parts and those strong, must be immune to grit, water and mud—must in short be nearly as simple and easy to care for as the present universal Mauser type. Because such a rifle had not arrived by 1914 the British adopted their 1914 Enfield. Because it had not arrived by 1914 every nation in the war was still using the manifestly inadequate and slow and out of date Mauser type of bolt rifle to check hostile rushes—work where the utmost speed of fire is called for.

However, the Allied armies had at their command various forms of self-loading rifles, or, rather, light-weight machine guns. They were somewhat heavier and more difficult to handle than what has been sought for under the term of self-loading rifle; yet they served the purpose to good advantage.

Thus there was the American Browning gun, already described elsewhere in this volume. Then there was the Lewis gun, used by the British, and the Chauchat gun of the French, with its characteristic semi-circular clips. But inventors were hard at work on a rifle weighing but little more than the standard infantry rifle and provided with a self-loading mechanism of simple construction. Such a rifle in the hands of every man in an infantry body could work untold havoc in the ranks of an advancing foe.

SIGNALING BY INVISIBLE LIGHT

An interesting method of secret signaling was devised by the Allied engineers. This consisted of flashing in the ordinary heliograph code, but using infra-red light waves for the message in place of the visible portions of the spectrum. Unlike wireless and like light, a sheaf of these infra-red rays can be sent in a desired direction; they do not spread in all directions from the point of transmission. The intended receiving station knows whence the message is coming, and exposes in the proper direction a screen sensitive to these rays. The enemy would be able to pick the message up with the aid of a similar screen; but he does not know where to look, and so can intercept the message only by the rankest chance—one probability in millions. Accidental interception is barred by the fact that these rays affect only certain substances, and can not be caught by any random object that happens to lie in their path. The ultra-violet would serve as well, save that it does not possess the heat value of the infra-red; and this heat-value is employed in reception.

THE MAN-KILLING RIFLE

The General Principles Governing Its Design and Use

THE big gun is designed to shoot over long distances; and as pointed out in another place, to achieve this result it is necessary to shoot up into the air and allow the projectile to fall out of the air upon its target. The shell may be a matter of miles above the ground at the highest point in its path, and this makes no difference; for the gunner is in no way interested in any spot other than the single, fixed one upon which his fire is directed. It matters not in the least how his shell reaches that spot, provided only it reaches it.

Rifle fire is something else. Unlike the case of the big gun, the extreme range of a rifle—the distance to which it will carry when pointed a little less than 45 degrees from the horizontal—has absolutely no bearing. It is a by-product; not sought for by the designer, not cared for by the user, absolutely not considered by any one. The ballistician in military service does not care whether the bullet fired at the optimum angle will carry 4,000 yards or 4,000 rods or 4,000 feet. He judges the value of the rifle by its extreme range no more than the real estate man judges the value of a house by the number of sparrows that fly past it in a given time.

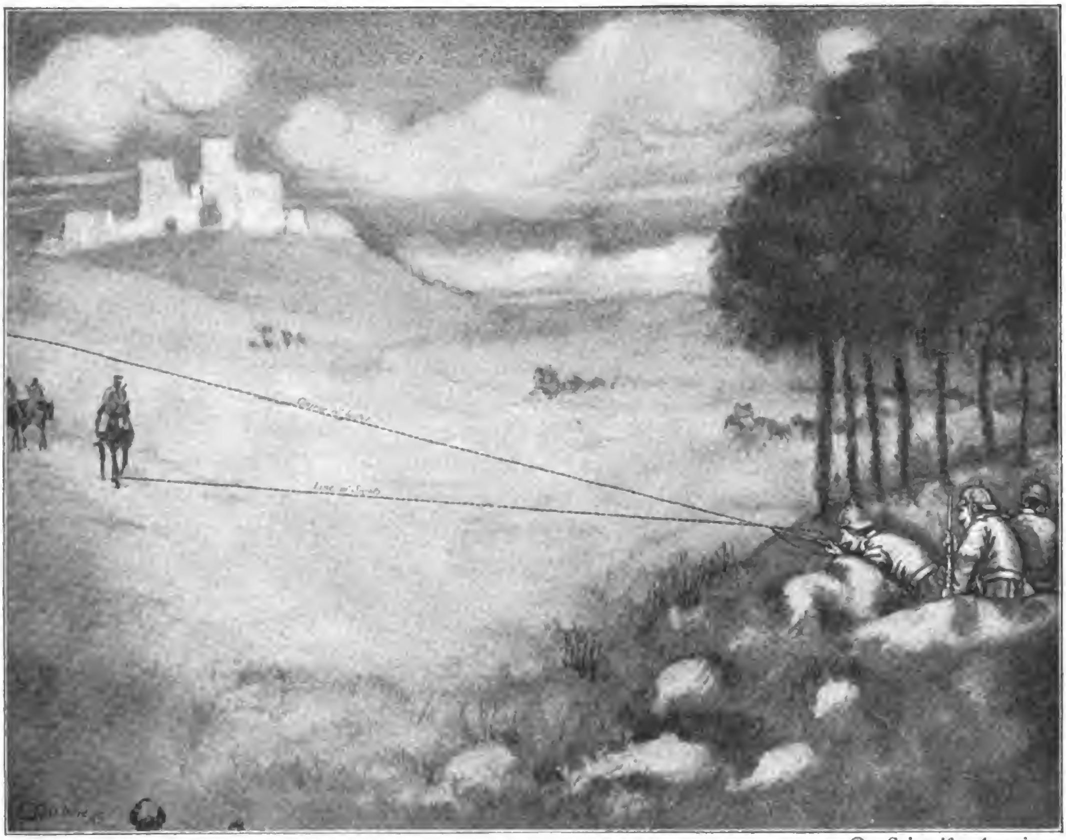
THE FLAT TRAJECTORY

The reason for this attitude is that the rifle is intended to be used in real, honest-to-goodness fighting against a foe whom you can see —it is not for the long distance sparring from and at entrenched positions in which the big gun shines. You do not shoot up a *position* with rifle fire; you reserve this weapon for use against *men*. To a certain extent this means sniping and sharpshooting—picking off the incautious chaps who show a bit of their arms or heads over the top line of a trench or around the side of a tree. But far more it means—and of far greater significance is this meaning—that the rifle will be used against an advancing body of the enemy.

This introduces a new complication. A fortified position has no choice but to stay where it is while you try to wipe it off the map. With a moving hostile force the case is different. Such a force may be 1,000 yards away when you start to shoot at it. If your bullets then have to loop the loop to get such a distance, you must reckon with the fact that the enemy is moving toward you, and allow for the speed with which he progresses. You must then drop the bullet in the right spot with great precision. But if you had a bullet that would fly in a perfectly flat, straight line for a distance of 1,000 yards before beginning to fall off, you could level your piece and blaze away—and the advancing foe would be within your line of fire for every step of the 1,000 yards over which he must pass in order to get at you.

Now for the military rifle in actual use the extreme range is 1,500 yards; but this is very uncommon. A thousand yards sometimes sees the beginning of rifle action, but often there is nothing but the most desultory firing until the hostile parties are within a far less distance of one another than this. So the thing for which all ballisticians strive is a rifle that shoots flat over fighting ranges from 1,000 yards down. Success in this search will obviate changes in the sights during action and will minimize the cost of errors of ranging and of judgment. After that range can go hang; for rifle fire is not effective enough to be worth the expenditure of ammunition at half the extreme range of the rifle. So the surest way to prove that you don't know the first principles of the military rifle is to talk about its range. The man who knows, says Captain E. C. Crossman, the well known small-arms authority, asks just two questions: "How fast can the magazine be recharged? How flat does she shoot?"

The answer to the latter question takes a rather interesting form. If a bullet goes straight up and then straight down, you must stand on the exact spot where it will strike in order to get hit. If it falls almost but not quite straight, you can move a few inches from the point where it would hit the ground, and still get shot. As its trajectory becomes flatter and flatter, it will hit a man further and further removed from its ultimate landing spot. If it were possible to make its path a perfect straight line it would hit a man anywhere in that path. So it is customary to rate the bullet according to the percentage of dangerous territory. If it has to be shot at such an elevation, in order to reach 1,000 yards, that it will only catch a man in the last 100 yards of its flight, it is said to have a danger zone of ten per cent. If it can be shot so low that it will fly 1,000 yards and hit a man at any point of its flight, its danger zone is of course 100 per cent.



© *Scientific American.*

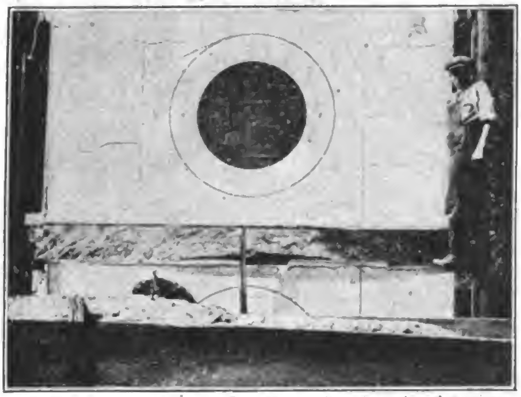
The Flight of a Rifle Bullet

A rifle bullet's flight is not perfectly flat. In fact, it is curved. After leaving the rifle the bullet curves upward and gradually swings downward again as its force becomes more and more expended. In this drawing is shown the sighting line as contrasted with the flight of the bullet, proving that the line of sight and the bullet's path are not parallel. The sights, however, take care of the difference.

THE LIGHT BULLET WITH THE SHARP NOSE

Way back in the 50's, a British officer stationed in India, one Colonel Jacobs, discovered that if you sharpen the bow of a bullet you cut down air resistance, just as sharpening the bow of a boat cuts down water resistance. It is true that this will make little difference in the ultimate range; and for this reason con-

temporary mathematical sharps were inclined to scoff at the Colonel's findings; and these went unattended until 1905, when the Germans made, independently, the same discovery. They found that so much did a sharpened nose cut down the terrific resistance of the air that they could shave down their army bullet from 215 grains to 154 grains and still have enough heft to overcome the atmosphere's opposition to flight, retaining the same proportion of the original muzzle velocity as with the old heavy bullet. This meant, in turn, that the same powder charge would give a greatly increased muzzle velocity and hence a greatly increased velocity throughout



Courtesy of Scientific American.

Long-Range Target
Used in the United States and England.

the path; so that finally the flight of the bullet would be much flatter.

In other words, the new cartridge gave a danger space of more than 500 yards—500 yards of space in front of the rifle over which the bullet nowhere got up high enough to pass over a kneeling man. This makes aiming a one-dimensional problem rather than a two-dimensional one; all you have to do is get the right direction. It is entirely the result of a flat trajectory, which in turn comes from high muzzle velocity, which in its turn can be had only with a light bullet. And light bullets are of no use if they fall off quickly from air resistance, and nothing but the sharp point will prevent this. So the Germans, by figuring this thing out correctly, made a big advance in the theory and practice of rifle action.

The Germans termed their new bullet the *Spitzgeschoss*, or, in English, simply the pointed bullet. It is ordinarily called a "spitz," and English-speaking practice is to corrupt this to spitzer. All there is to it is that the bullet is pointed, like the end of a nicely pointed pencil. It was promptly taken up by the French, the Austrian, the British and the American armies. In the latter case it meant the elimination of the old blunt-nose 220-grain bullet, with muzzle velocity of 2,200 feet per second, in favor of a spitzer of 150 grains and 2,700 foot-seconds initial speed.

The rifle is the machine that shoots the bullet. In the last analysis it is a gas engine. The barrel is the cylinder; the bullet is the piston, which is moved by the explosive force of the gas developed behind it; and there is the exhaust after the gas has done its work. To this extent the rifle works just like the automobile engine. But the rifle is a one-stroke-cycle engine, and at that there is but one cycle; the piston never makes a return stroke.

THE RIFLE'S DUTY AND HOW IT IS PERFORMED

Aside from the barrel and the bullet, the rifle comprises the firing mechanism—which finds its automotive counterpart in the ignition system. The chauffeur has to create a great many sparks in his combustion chamber, one for each stroke of the piston, so he does this electrically, by means of magneto or battery. The rifleman, with only one stroke of his piston, needs but one spark, and this is best produced mechanically. The problem is complicated by the necessity for opening the breech to insert the cartridge, and closing it again so that it shall be gas-tight when the explosion takes place, and then transmitting into this gas-tight combustion chamber a mechanical impulse sufficient to create the spark. On top of this comes the demand that the chamber take a number of cartridges at a single loading, and automatically bring them, one after another, into the firing position, and automatically throw out the empty cartridge case (see the remarks on fixed ammunition, page 1). In fact, the analogy with the gas engine comes perilously close to breaking down here; because the gas engine takes an indefinite number of strokes

with the same old piston, while the rifle has to have a new piston or bullet for each stroke. It is all this that makes the rifle a complex assembly of moving parts, instead of the very simple contrivance of flint-lock days; and naturally enough this means that the various nations will use rifles that differ in many of their details.

Various indeed were the rifles used by the warring nations. Germany's Mauser was the best, with the 155-grain bullet and initial velocity of 2,900 foot-seconds. This rifle, a clip-loader, weighs nine pounds. In its simple sight-setting arrangement, its finish and accuracy, and in the high speed of its bullet, this arm deserves the first rank. It has a long sword bayonet, usually carried in a scabbard at the belt. With its long barrel and long bayonet it gives a stabbing length of 69 inches, beating all the others except the French. The eight inches advantage which the German has when it comes to crossing bayonets with the Tommy easily turns the tide of battle in his favor, if both the adversaries are of equal strength and skill.

The French rifle has a tubular magazine in the forestock, like an American sporting arm. The cartridge is the most interesting feature. It carries a solid copper-zinc bullet, which is not only pointed before, but also tapers behind, so that it is a true boat-shaped bullet. The layman usually has difficulty in understanding what bearing the shape of the stern can have upon the resistance offered by the air to the bullet's flight; but if he will make a mental contrast between the amount of lateral skin-friction suffered by a well turned boat and by a square-sterned scow, he will realize that there is a difference after all. The French bullet is truly stream-lined; it weighs 170 grains and has a muzzle speed of 2,400 foot-seconds. The magazine is loaded, not with clips or chargers, but by the slow process of cramming in one shell after the other. For this, of course, there is not the slightest justification; no soldier should be asked to handle his bullets except in clips or other units that fill his magazine.

SWAPPING HORSES AT THE CROSSING

The British experience with rifles during the war is highly instructive. They were caught, at the outbreak of hostilities, in the process of changing from the old .303 caliber Lee to the Enfield-M, of .276 caliber, but not sufficiently changed, especially with reference to cartridge production, to make possible its entire adoption to the exclusion of the older model. It will be understood what a calamity it is when an army is equipped partly with one rifle and partly with another; and this disaster is raised to the *nth* power when the two pieces in question are of different caliber.

Courtesy of Scientific American.

The Silhouette

Man figure target, used for rapid fire.

As a matter of fact, for some time at the beginning of hostilities the British had to submit to this extreme inconvenience, judging rightly that it was preferable to no rifles at all. But the facilities for making the old were so much greater than those for making the new that it was the new which had to go overboard, in spite of its recognized superiority—so the British went through the war with a 215-grain bullet giving a velocity of 2,000 feet per second, instead of the 174-grain projectile that would have started on its way at a speed of 2,440 foot-seconds.

As far as the British manufacturers were

concerned, these remarks with reference to a return to older models apply both to rifle and bullet. But the American factories accepting British contracts were given the specifications of the new rifle with which the British Army would have been armed in another year or so had it not been for the war; only instead of making it for the new but temporarily abandoned .276 cartridge, it was chambered for the old .303 bullet.

Accordingly when the United States got into the war, our private plants had available some $15,000,000 worth of machinery, sufficient to produce from ten to fifteen thousand of these British rifles per day. The government had in operation only one comparatively small arsenal for the manufacture of American types; so the sensible thing to do was to adopt, for our new Army, the British rifle of 1914, which we were equipped to produce—but chambered for our 1906 cartridges, which we were also equipped to produce. This meant that we should be using two different rifles for the same cartridge, and by the same token, a cartridge different from those of our Allies.

Now firing the same bullet from different rifles involves no complication at all; the models are sufficiently similar so that a man who has learned to fire one could fire the other. But on the second count the issue was not so clear, and there was a great deal of criticism of the action taken. It seems, however, in cool after-analysis, that our Ordnance Department was in the right in ignoring the clamor that the new rifle be made to take the British cartridge so that our soldiers could replenish their ammunition supply from the nearest dead Britisher. It was easy enough to keep American units apart from British and French, or to supply them with British and French rifles when they were brigaded with soldiers of these nationalities, or to supply them with American cartridges in sufficient quantities when they were so brigaded; but the spectacle of two sorts of cartridges in our own Army would have been edifying indeed—for the Germans.

HOW A RIFLE IS SIGHTED

Various Forms of Sights Used on Military Rifles and How They Work

A RIFLE that will shoot into a dinner plate at 500 yards for a score of shots, and a set of sights that are cruder than those used on the ancient crossbow—this is the modern military rifle and its equipment. The simplest form of rear sight in the world—the quickest to catch, and the most accurate to use—is a round hole in a plate close enough to the eye to save searching for it when the rifle is thrown to the shoulder. But two of all the world's military rifles are so fitted. One of these, the rifle of the American service, has the principle applied in so faulty a manner that for fighting the peep is nearly useless. It is set too far from the eye, and it is too small in size.

The sights on a rifle are necessary, first to allow the firer to see over the elevated muzzle, second, to align the weapon accurately on the mark. Regardless of distance from the gun, if the mark is to be hit, the muzzle of the rifle must be pointing higher than the thing to be hit. At 1,000 yards the bore—the line of the barrel—is actually pointing 40 feet above the target. During its flight the bullet falls this distance and hits the mark. This is true of the present government rifle, but in the case of the old black powder .45-70, the barrel was actually pointed 175 feet above the mark at 1,000 yards.

WHY ADJUSTABLE SIGHTS ARE REQUIRED IN LONG-DISTANCE SHOOTING

By raising the rear sight, the rifleman can see over the raised muzzle, and when the front sight is put into the proper relation to the mark and the rear sight, the rifle is pointed the correct distance above the target to overcome the effect of gravity, and still the rifle-

man is aiming at the target over his line of sights.

When the government rifle is sighted for 1,000 yards, the rear sight is roughly 5-16-inch higher than its position for 100 yards, and the muzzle of course has to be raised that much to bring the front sight again into line with the rear.

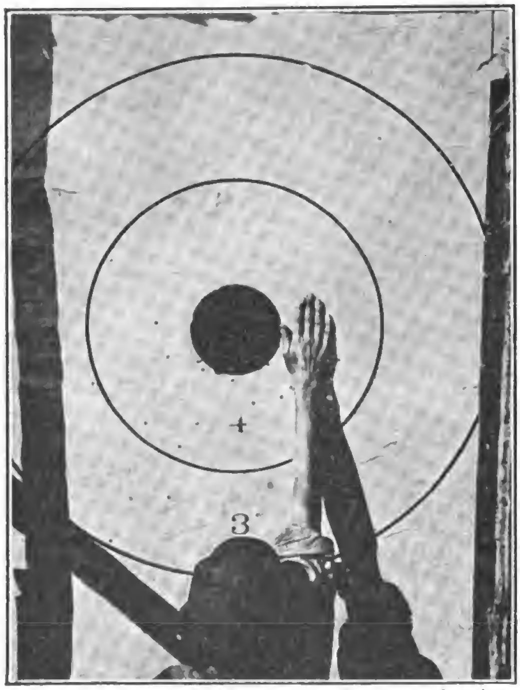
At this thousand-yard range, an error in the alignment of front and rear sight of just 6-1000-inch—six one-thousandths—will make an error at the target of 10 inches. In other words the rifle pointed at the center of a man's body, would miss him if the error of 6-1000-inch were made laterally, sideways. Four times this error in aligning the sights up and down—24-1000 inch—would put the bullet above or below the soldier if the sights were pointed for his middle and the rifle were sighted to hit there when normally aimed.

This is the reason why the particular rifle shooters demand peep sights. It is the reason why the protests of thousands of American military rifle target shooters compelled the government hastily to install an afterthought peep on the Krag Jorgenson of one model, why our Springfield has a peep, and why the Canadian Ross has a peep sight, a peep set in the correct position close to the eye, not true of any other rifle in the world that is intended for the fighting man.

The open sight is merely a bar with a notch cut in it, set usually near the rear end of the barrel. When the front sight is drawn into the correct position in this notch, and then the front in turn is placed in the correct relation to the mark, the rifle is sighted correctly. Unhappily this process entails optical impossibilities, and a compromise, more or less satisfactory, has to be used with the open form of sight.

The mark, the front sight, and the rear sight lie in three different planes. The eye sees no two of the three sharp at the same time. The rear sight, for example, lies say 15 inches from the eye, the front sight 30 inches, and the mark a distance measured in yards. So the unhappy user of the open sight has to make his eye leap sprightly from one sight to another and then to the mark, the muscles of accommodation altering the focus of the eye for each one as one alters the focus of the lens of a camera for varying distances.

Normally the shooter sees the rear sight sharp for an instant, as he draws the front sight into the notch, then trying to hold the front sight in its correct position, he focuses on the front sight and puts that against the mark, and then focuses on the mark. By this time the rear is very blurred and fuzzy because the eye is not in focus for something 15 inches away, but for infinity of distance. The great change, of course, is from front to rear



Courtesy of Scientific American.

American Target

Used for two hundred and three hundred yards. Bull's-eye is only eight inches.

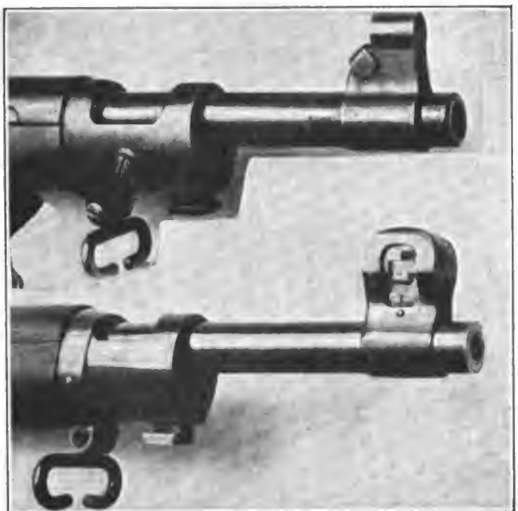
sight, because changing in focus for an object 15 inches to one of 30 inches, is a far greater strain than changing from 30 inches to 300 yards.

Not only do old eyes with stiffened muscles of accommodation fail to get accurate results with open sights, but young eyes cannot do the work with the open that they can with the peep. Into this list must be added the further evil that an excited man will not stop to draw the front sight into the right position in the notch of the rear sight, but will put it merely into approximate position, and let

fly. It is an eye strain, and a slower method than the peep, but still the Continental authorities cling to this crude sighting method.

THE CASE FOR THE PEEP SIGHT

The peep sight, on the other hand, depends on a sound optical principle for its usefulness, and that the principle is sound is proved by too many years of the use of this form of sight. Crossbows dating clear back to the 14th century show peep sights as part of their equipment, one example belonging to an English nobleman, showing five different peep holes, one above the other for different ranges.



Courtesy of Scientific American.

Our Favorite Rifle and the One We Had to Use in the War

Here are two rifles, the Springfield and the modified Enfield, as viewed at the muzzle end. The Springfield appears above, while the Enfield is shown below. The foresights of these two types differ materially.

The light in the center of the round hole close to the eye is stronger than the light around the edges, and the eye, if left to itself, goes to the center of this hole every time. Queerly enough if the hole in the peep is about the size of the iris of the eye, the rim surrounding the hole in the sight nearly disappears from view, even though it be 1-16 inch thick or even more. The well-known Lyman sight for sporting rifles illustrates this latter form.

If the rifle is such and the peep is so arranged that it can be used close to the eye without recoil endangering the shooter's face, a very small peep, 3-100 inch across, can be used, and still allow a perfect view of mark, country around it, and front sight. Here it is like looking through a pin hole in a sheet of paper against the eye. Also the small hole tends to act like the diaphragm of a lens, sharpening the image brought to the eye.

In using the peep set in proper position with relation to the eye, it is utterly ignored and is seen no more than a person sees the frame of the window through which he is gazing. The eye goes to the center of the hole if left alone. So the problem of our rear sight is immediately solved, the shooter has left only the front sight and the thing to be hit. Also not only does the shooter ignore the peep, but he does not have to fight with a blurring image of the rear sight in his endeavor to shoot accurately. So our gain is twofold, quickness in sighting, and accuracy in sighting, to say nothing of the relief given to men with defective eyesight, or with the failing eyes of age.

But one military rifle correctly solves the sighting problem, and that is the Canadian service rifle, the Ross Mark III. Here the rear sight is set back on the bridge at the rear end of the receiver, hardly 3 inches from the eye. When the leaf is raised to vertical, a plate carrying the round peep hole is exposed to view. Above the round hole is another U notch for occasions when the peep cannot be used, such as very bad light and badly defined objects. For target-shooting considerations the hole is very small, about 6-100 inch, and in poor light the rifleman cannot always use it. It would be more practical for sighting if opened out to a tenth-inch diameter. As it is, however, it is so near to the eye that the rifleman sees through it without effort in ordinary lights.

The other rifle fitted with a peep, the new Springfield of the American service, loses all the virtues of the peep by the sight being set too far from the eye. With the largest size hole but 6-100 inch, the sight is perched on the rear end of the barrel, about 10 inches from the eye, and only by strain and care can the small hole be seen, and the mark caught through it.

SIGHTS OF THE VARIOUS EUROPEAN ARMY RIFLES

All other rifles of military type use open sights well up the barrel, the notches cut either U or V shape, usually the latter. Just as the peep sight is more efficient when close to the eye, the open is cut clearer when set a distance away, being then nearer to the focal plane of the front sight and the mark. Although the open military sight is seen more clearly when it is set a good distance from the eye, it cannot go too far away because then the distance between the sights is cut down, and errors are increased in the same proportion, on the target.

The German Mauser sight is known as a ramp sight. It is a leaf hinged at the forward end, and lying flat on the barrel. A ramp or inclined plate lies between the bars of the leaf, in one model. When a locking button in the sight is released by being compressed between thumb and finger and is pushed forward up the ramp, it carries the sight leaf upward, giving elevation for the various ranges, which are marked on the side of the ramp. The sight locks itself when the button is released.

The British sight, aside from being the old crude open type, is the best of all the fighting rifles. The open feature could be altered at small trouble, and a peep provided.

Pushing the elevating bar forward up an incline gives elevation, the ranges being marked on the leaf of the sight that normally lies flat on the barrel. A wind gauge is provided, and by means of a fine worm screw, the fine changes necessary in long range target shooting can be made between the coarser yard graduations. Saving the feature of being an open sight, it is probably the most practical of all outside the Canadian back sight.

The American Springfield sight has grave errors, being neither a practical military sight nor an efficient target sight.

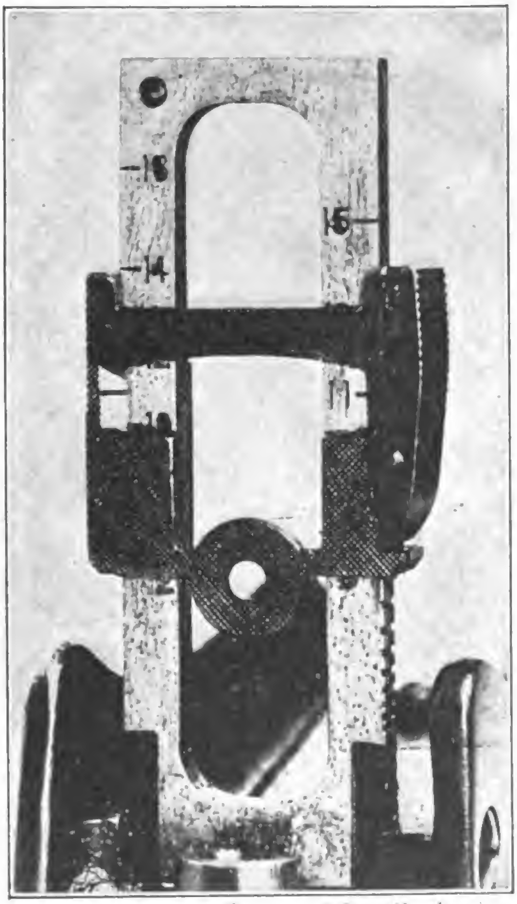
When the leaf is raised vertically for use, it is exposed to blows, and is more or less in the way. Standing vertically, the green soldier perceives a notch of U shape, cut in crossbar of the leaf, and good for 2,850 yards,

© *International Film Service.*

A Rifle That Has Been Acknowledged the Best of Any

Every army has its own ideas about rifles, yet it has been pretty generally acknowledged that the American Springfield rifle is the best of any, especially in the hands of the American rifleman.

then below that another notch cut in the slide, and below that a triangle milled out in the plate of the slide, and a third notch cut in that. Below this is a round hole, the peep sight. If the range is 500 or 600 yards, raising the slide leaves an irregular shaped hole between it and the base of the sight,



Courtesy of Scientific American.

Rear Sight of the Enfield Rifle

The slide is self-locking. This sight is easily read and set. It is very close to the eye.

through which the rookie invariably proceeds to aim. So the green man has in front of him three different notches, a peep, and possibly a hole between slide and base that looks as if it might be intended to aim through.

When the sight leaf is laid flat on the barrel, the battle sight is in view, a notch of U shape, sighted for 530 yards. This is one of the most absurd features of the rifle, a sight carefully designed to do away with all the virtues of the flat trajectory of the very modern army rifle. Being sighted for 530 yards, the rifle shoots more than 2 feet high at 300 yards, and the soldier is told to aim that much low. Inasmuch as the soldier is not disposed to judge distance carefully in the heat of a battle, and inasmuch as a battle sight is supposed to be a sight with which you can hold on the enemy regardless of his range if he is within its scope, the effect of the American sight is to put the entire sheaf of fire over the enemy at the most useful range.

THE FUNCTION OF THE BATTLE SIGHT

What should be done, is to sight the rifle with this battle sight—an emergency sight we might call it—for 400 yards, when the bullet would rise nowhere more than 10 inches higher than the line of sights and the soldier could then hold on his foeman at any range up to the 400-yard limit of this sight. This is utilizing the flat shooting of the rifle as it was intended to be utilized—that is, letting the very flat flight of the bullet take care of all errors in range estimate and so make range estimate unnecessary up to the limit of the battle sight. To hold high or low for various distances is to get back into the class of the most old-fashioned, slow-speed. high-trajectory rifles, where one had to hold high or low or change sight setting to compensate for the fall of the bullet.

When, because of its high speed, the bullet from the German Mauser does not have to rise higher than 20 inches to hit the center at 500 yards, then the battle range and the battle sight of that rifle is nearly 500 yards long. Up to that distance the sight setting does not have to be changed, the 500 yards setting catches nearly anything in between. But the point-blank range of the Springfield is not 500 yards; and its battle sight should therefore not be set for 500 yards.

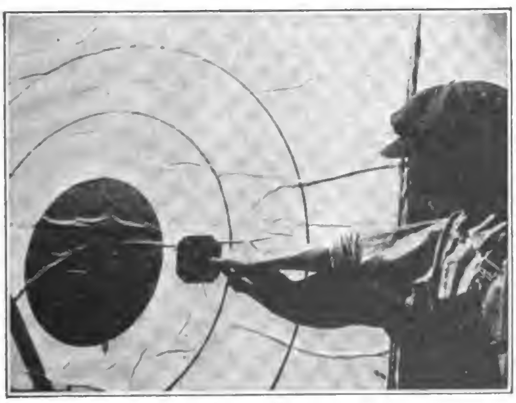
TELESCOPIC SIGHTS FOR THE SNIPERS

Whatever the shortcomings of the United States in the way of preparedness, it was one of the first to develop a telescopic sight especially designed for use on a military rifle. Such sights have of course been used for years on target rifles and occasionally in military

service, but even those intended for use on sporting rifles were hardly suited to the rough use and exposure incident to active service.

In addition to its employment on machine guns for long-range firing, the telescopic sight is intended for the use of trained riflemen, who have the skill to take advantage of its superior optical powers. Those issued to each company are added to the equipment of the soldiers who have shown themselves most proficient with the rifle in target practice and in war these men would act as snipers when required.

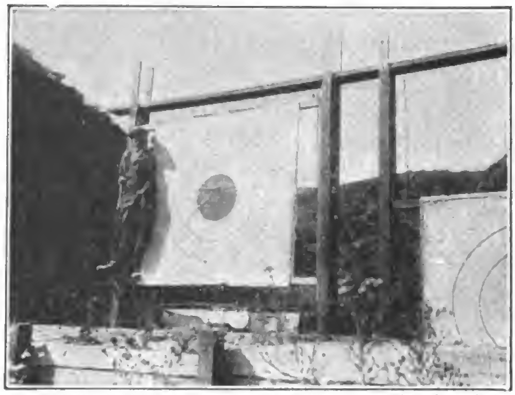
So far as known no country has contemplated equipping every rifleman with such a sight, for the very practical reason that the majority of soldiers would not have the skill to use it and that the opportunities for use are more or less limited. It is a very fair rifleman who can hit a man at 500 yards and at that range a man is quite a visible target to the naked eye unless carefully concealed. A larger target can of course be hit by the same man at a longer range, but the visibility is also increased on account of the size. In other words ability to see with the unaided eye and ability to hold the rifle steady enough to hit are about equal with the average man even after a good deal of training; and ability to see is far ahead of ability to hit in the case of a poorly trained man. It is the man who has so great skill with the rifle that he is handicapped by the limitations of unaided sight for whom the telescopic sight is intended.



Courtesy of Scientific American.

The Spotting Disk of a U. S. Rifle Target

The latest telescopic sight, adopted by the United States Army, is mounted on a service rifle. It has a dovetailed slot that slips over a corresponding piece fastened to the breech of the rifle and is held in place by a catch, the whole device being readily removable so that it can be carried in a leather pouch for protection when not required.



Courtesy of Scientific American.

U. S. Mid-Range Targets

Used at 500-600 yds. Bull's-eye 20 in. across.

This telescopic sight has a magnifying power of six diameters. Let the reader draw a one-inch square, and beside it a circle six inches in diameter. Let him then imagine that the small square view shows the field of vision through the ordinary peep sight, with the marksman aiming at a hostile mark 500 yards away. He moves his gun about until his target appears in the center of the aperture afforded by the peep and just clear of the rectangular projection of the foresight. Then he pulls the trigger.

Let him turn his attention to the circle; if he is artist enough he might even draw a picture of some sort in the square, and copy it, enlarged, in the circle, filling both. But whether the picture be thus inserted or not, the field which in the ordinary sight appears as large as the square will, in the telescopic sight, occupy the space of the circle. Here the object of the shooter is to make his target fall upon the intersection of the cross-hairs.

The optical features of the telescopic sight differ from those of the ordinary telescope principally in that the length is made as short as possible by the use of prisms which so reflect the rays of light that they pass from

end to end of the rather square body instead of only once down a relatively long tube. Every effort is made to make the instrument dust and moisture proof, and a rubber eyepiece is provided to protect the eye so far as possible from the recoil of the gun.

The sight is set for range by turning the large milled disk at the front of the sight which is graduated up to 3,000 yards. Turning this disk operates a cam which in turn rotates the telescope up and down with respect to the bore of the rifle. Corrections for direction are made by turning the smaller milled disk which rotates the telescope from side to side. The rifle is aimed when the sight is correctly set and the rifle so pointed that the target appears at the intersection of horizontal and vertical lines in the telescope similar to those of a surveyor's transit. On top of the sight there is a table of useful information relating to the setting of the sight under various conditions.

THE NEW AMERICAN RIFLE

The Combination of British and American Design with Which the Draft Army Was Equipped

IT is out of the question for us to attempt even an outline of the rifles used in all the belligerent armies; and it is superfluous for us to do so, since there were no notable advances in this arm during or as a result of the war. A few words on the general structure of the rifle are, however, distinctly in order; so we may very well pause and examine rather closely the American arm adopted for use in the war.

The official title of this is "303 Pattern '17"; but because the word "Enfield" has been popularly attached to the rifle, and because Enfield seems to belong with Lee as naturally as Krag with Jorgenson, a worried proletariat decided forthwith that the rifle was the old Lee-Enfield of England, which even the layman had heard of as being out of date. In fact, however, the British-designed rifle made here for our draft Army has little in common with the old British Lee-Enfield.

The British rifle, pattern of 1914, commonly but incorrectly styled "Enfield," is essentially the Spanish or Boer Mauser, as we know that type. It cocks on the closing motion in the same way; in the same way it prevents trigger motion when the bolt is not entirely closed; it has the same locking lug arrangement, and practically the same form of bolt stop and ejector box; the magazine is the same, the floor plate lock practically the same. The changes necessary to adapt this .303 British rifle to our cartridge were not many. The bore was changed from .303 to .30, the magazine follower adapted to a rimless shell, the bolt head slightly altered, and the clip slot reshaped for our clip.

WHAT IS THE BEST RIFLE SIGHT?

The feature that immediately takes the eye is the position of the rear sight of the new rifle—"a position," says Captain Crossman, "for which I have argued for years in practically every magazine that publishes shooting or ballistic articles." It perches back on the receiver bridge, and is merely a very generous peep. Unlike the sight on our new Springfield, there is but one thing through which to aim—the large peep, which cannot be overlooked by any man with normal eyesight. This sight does not stand vertically, but leans slightly away from the shooter, the purpose presumably being to aid in reading the graduations. When the sight leaf is laid flat on the bridge, in its protecting wings, another peep stands up in the line of sight; this is the battle sight.

Where the peep sight of the latest Springfield is roughly ten inches from the eye of the prone soldier, and but .05 inch in diameter, the peep sight of the new rifle is only four or five inches away, while the aperture is

roughly .10 inch. The leaf is graduated to 1,600 yards. The slide—the movable portion carrying the peep—is self-locking, a release lever dropping into the notches cut, one for each 50 or 100 yards, in the side of the leaf. Because there is no intermediate stop between these marks, the target shooter would emit loud wails of anguish if asked to use the rifle. Also the lack of wind gauge—this is purely a fighting man's rifle—would make the favorite American sport of wind-doping at long range as impossible as a trepanning operation with sledge hammer and cold chisel.

The battle sight is ranged for 350 to 400 yards. A rapid-fire string of ten shots by a good marksman from the kneel scored nine hits on the silhouette and one close up on the four ring. Here the front sight was held just touching the bottom of the figure; so judging by this, the rifle is sighted far more satisfactorily for battle or fixed range than is the new Springfield, which in order to hit a prone man at 200 yards has to be held two feet below him.

The front sight is too narrow, worse than that of the Springfield, because the same width —.05 inch—and farther from the eye. Captain Crossman has repeatedly pointed out that

Courtesy of Scientific American.

Enfield and Springfield Rifles

Springfield above, Enfield below. Note positions of rear-sights on two rifles.

the broad front sight can be caught in any light, and against any background, whilst the stingy sight like that of the new arm is often completely lost. This gun by all means should have a sight not less than .08, preferably .09 inch in width.

Instead of using the hood or cover over the front sight, as on the new Springfield, the new rifle has two high wing guards, rising on either side. So the front sight is less protected than that of the Springfield, less easily caught when shooting in a hurry, less

Courtesy of Scientific American.

Springfield vs. Enfield

Comparing the old and new types of American rifles.

easily seen because of the flood of top light pouring down on it. The wings give one the uncomfortable feeling of having to choose between three front sights.

The queer phase of the rear sight of this rifle, which of course is straight British through and through save for the slight change in graduations, is that it represents a complete turnover of British opinion. We have Johnny Bull, consistent and pig-headed devotee of the open sight, bobbing up not merely with a peep sight, but with a peep set in the right position and large enough to make its full advantage available for snap shooting!

MECHANICAL FEATURES OF THE NEW RIFLE

The bolt handle has a peculiar ramshorn twist, curving down and then back toward the butt, to shorten the reach when the rifle is being reloaded at the shoulder. At first sight, we gave three cheers; after trying it out we reversed our decision. The curve brings the handle just forward of the knuckle of the trigger finger. Gripping the rifle and putting the finger through the trigger guard tended almost invariably to raise the bolt

handle so that the rifle could be neither fired nor made "safe." Also in firing over a parapet the bolt handle has a pleasant tendency to jam into the knuckle from the recoil. The idea is good, but has been overdone to the point where it may be regarded as a serious defect.

Courtesy of Scientific American.

Rapid Fire

Working the bolt in continuous fire.

The safety is not a part of the bolt sleeve as in familiar models, but is pivoted in the right side of the receiver, abaft the bolt handle, and works parallel with the barrel. Pulling it back operates two plungers entering recesses cut, the one in the bolt handle, the other in the firing pin head. Because the former recess must be exactly in line with the plunger, the slightest upward motion of the bolt handle, as before remarked, prevents the soldier from putting on the safety.

The magazine is essentially that of the Springfield and Mauser, but holds six cartridges instead of five, due doubtless to the more compact rimless 1906 American pills.

The British rifling is adhered to, left hand twist with five equal grooves and lands. The Springfield has four lands with right hand twist. Apparently the new weapon likes our bullets, for 75 shots, ten of them rapid fire, without bullet lubricant, failed to deposit even .0001 inch of metal fouling on the lands, which is not the case under the same conditions with the Springfield.

The stock has a sort of pistol grip, and gives the same appearance as the Lee. It is extremely uncomfortable in any position, particularly the prone. The butt plate is badly shaped, and bruises the shoulder—where my own is case-hardened and usually immune to recoil. The stock pounds the jaw; always these military people make the obvious error of too much crook in the stock, and this is intensified by long range, which carries the head still higher and makes the stock drop still more.

The rifle has 26-inch barrel instead of 24, the length of the Springfield, and is 46 inches over all against 43¼ for the Springfield. Also it weighs ten pounds or more complete, about one pound more than the average Springfield. Much of this weight seems to lie in the barrel at the breech end, where there is a lot of unnecessary hardware. With a long and hungry bayonet on the muzzle, making 11 pounds in all, the handling of the arm takes a pretty husky citizen; it would be better for the sort of fighting now in style if nearer nine or nine and a half pounds with bayonet fixed.

The bolt works smoothly but there is a tendency to drive the rifle from the shoulder in rapid fire, and Captain Crossman says he can make better going with the Springfield bolt—that is, with a good one. Some Springfields are impossible.

Courtesy of Scientific American.

Rifleman Prone

Showing danger of raising bolt handle with his knuckle.

There is no magazine cut-off as on the Springfield—which is correct; there is no need for one with a clip-loading rifle. The magazine follower, however, as on the Springfield, holds the bolt open when the magazine is empty. Accordingly drill with the empty rifle in the firing motions is made possible only

by the issuing, with each rifle sent to the camps for drill purposes, of a "depression follower," which, held under the edges of the bolt wall, allows the bolt to go forward without obstruction and permits use of the rifle as a single loader. The purpose of holding open the bolt when the magazine is empty is to prevent the excited soldier from continuing indefinitely the motions of firing on an empty chamber, as experience proved that rattled troopers frequently used to do with the Krag in action.

In conclusion, the new rifle is a beautifully finished arm, equal to any sporting rifle. On the whole, it seems superior to the Springfield. Outside of the feature of the rear sight, one might perhaps prefer the older arm, not because of long association but because of better position of bolt handle, lighter weight, better safety and better stock—although that is bad enough. Of the two, however, both handled by men of the same length of training, the 1917 weapon would win hands down because of that splendid, fool-proof, easily caught rear sight, as compared to the complicated, unsatisfactory Springfield sight. Susceptible as it is of further great improvement,

Courtesy of Scientific American.

Springfield Rifle Bolt

The handle is well forward of the trigger finger joint.

as a man-killing weapon, Uncle Sam's new shooting iron stands without a superior in the infantry rifles of the world's armies.

BAYONET FIGHTING

An Ancient But Indispensable Form of Man-To-Man Combat

ON the face of it, the most ridiculous phase of modern fighting is the fact of the efficiency of a sharp knife stuck on the end of a clip-loading, flat trajectory magazine rifle.

The contrast between the two weapons, the sharp knife and the rifle, is the contrast of 2,000 years. By itself the knife is not so efficient as the short sword of the legions of Cæsar. On the empty rifle the knife is not so efficient as the spears of the Macedonian phalanx.

It was logical enough in the days of the muzzle-loading rifle with the delay of a half minute or so from shot to shot, and the ridiculously close range at which our forefathers fought. It was logical enough when the rifles and muskets of those times would hardly hit a barrel at 100 yards, and would miss an ice-house at 400 yards. It was logical enough when the fashion of fighting sent cavalry galloping past the front of massed infantry until the fire of the footmen was drawn and the horsemen could smash and hew their way down through the close-packed ranks of men with empty rifles. Always horses disliked bayonets. When the infantry rally early enough to let the horses get a good view of the bristling, gleaming hedge that stands round each square, the steeds turn at the last moment and refuse to immolate themselves at the behest of their riders. Then the only recourse of the peeved cavalrymen is to lean far over and slash at the infantry with the long sabers given them for that especial purpose.

A STUDY IN VIOLENT CONTRASTS

But those days are gone. Cavalry rarely charges in the face of magazine, clip-loading

rifles. If it becomes thus incautious it merely helps to send up the prices of American horses. The normal infantry combat outside of entrenched positions opens at 1,200 yards. The modern infantry rifle speaks thirty to thirty-five times a minute. It can be recharged with a fresh clip in 4 seconds from the last shot of one clip to the first shot of the other. It trenches, where one might expect sharp steel to prove useful, but it has helped Germans to drive Russians out of the most temporary positions where the fight started at long range, and it has, in turn, induced the Teuton to turn his back hurriedly on Petrograd and to commence an accelerated progress toward Berlin.

Bayonet Practice

The soldier at the left is using the "long thrust," while his opponent is using the "hand parry" to prevent an untimely end.

shoots into a circle the size of a barrel-head at 1,000 yards instead of at 75 yards. No smoke conceals the movements of the other force, bullets fly fast and flat, and do not miss because of slight errors in sight-setting.

With all this true, the use of a sharpened knife 18 inches long, on the end of such a magnificent weapon as the modern rifle, would seem the act of a child or a madman.

But, not only has the sharp knife proved its usefulness in the close fighting between

Up to the time of the Russo-Japanese War the bayonet had gradually fallen into disgrace. The experience of the British in the Boer War, in 1900, when the Boers had no bayonets, and the British found that the Boers had merely decamped, when they got close enough to the Boer positions to use their own, seemed to prove that the long knife was about as useful a part of infantry equipment as a pair of brass knuckles would be.

In 1903, between the Boer and the Japa-

nese Wars, the United States got out a new rifle, a modified Mauser, clip-loading, and of the most modern type. On this rifle, the new Springfield, our ordnance people put a compromise, the smallest bodkin that ever rifle wore. It was a rod bayonet that normally rested in the stock below the barrel like the old style ramrod. It extended about a foot beyond the rifle muzzle when in place for service, was about the size of a pencil, and had a sort of a point—that is, a heavy enough lunge of the rifle would probably have inserted it into the anatomy of an enemy.

The Japanese and Russians upset all the traditions of three years' standing, established by the Boer War. Probably a poorer exhibition of rifle shooting never was given than that put up by the Russians and Japanese, but they made up for their deficiencies by savage attacks with the bayonet in the face of all the machine guns and high explosives and magazine rifles that modern science had conjured up.

Immediately the United States chucked the rod bayonet off its new rifle, and installed a formidable sword bayonet, carried normally in a scabbard like the bayonets of other powers, extending 16 inches beyond the muzzle of the rifle, double edged at the point, and sharp all the way down one edge.

American Soldiers Charging German Dummies

While training, our troops made bayonet charges over the top in which "automatic Huns" sprang up (literally) to resist the charge.

Detached from the rifle and gripped by its very efficient handle, it makes no despicable weapon; it can be used to dig hasty and temporary shelters, and it can be slipped on the rifle in an instant. Of course, like all other bayonets, it does not interfere in the least with firing the rifle while it is in place on the muzzle.

THE RUSSIAN'S FAVORITE WEAPON

The Russians have made more use of the bayonet than any other nation engaged in the

recent war, a natural result of poor riflemen and a superabundance of soldiers, and a more or less half-civilized people who naturally trend, like all half-civilized people, to the use of cold steel.

The Russian bayonet is never detached from the rifle, and no scabbard is provided for it. It is quadrangular in cross section, with the point chisel shape, and it is 16 inches long. The blade is set at a slight angle to the barrel, the point higher than the muzzle. Queerly enough the blade is browned or "blued" like the barrel of the rifle, aiding to protect it from the elements, but taking away from the effect of the bristling line of shining steel that the perturbed foe normally sees when attacked by the bayonet. The scare is half the effect in a bayonet charge; often the opposing troops do not wait to argue out the matter.

The few reports we get of the savage fighting of the Balkan wars of 1912, agree that the Bulgarians took to the bayonet at the slightest provocation, and that the Turks hastily left at the first sight of the long line of bright steel that suddenly appeared. One instance is given of the attack of a whole brigade with the bayonet that began at 400 yards. That is, the Bulgarians fixed bayonet and charged the Turks at a distance of four city blocks from the Turkish position.

The late war has gone far to prove the old claim of the infantryman, that infantry is queen of battles. You can pester the foe and learn of his movements with your cavalry, and you can pound his trenches to bits with your artillery, but you cannot take and hold his position without the infantry. Apparently we are to add to this the proviso that you cannot do this without the infantryman's bayonet.

The British paid much attention to the bayonet in training their troops. Part of the training game is to rush an "enemy" trench,

Benny Leonard Shows Marines Boxing Moves

The close relation between boxing proficiency and bayonet thrusts was shown to the Marines during the war in their training at the Mare Island barracks by the world's champion lightweight.

leap it, and plunge the bayonet into sacks on the other side representing the foe. Another phase is rushing man-size figures hanging by ropes and lunging the bayonet through them without halting the rush.

BOXING WITH COLD STEEL INSTEAD OF PADDED GLOVES

Of course, this is the field training. As preliminary training the recruits are carefully trained in attack and defense with the bayonet, just as men are taught to box. Giving no other odds to either side, the trained man can simply murder an untrained opponent.

In the American Army, bayonet exercises are part of the course, and bayonet fighting with dummy rifles and blunted, light, springy rods for bayonets is well worth seeing.

Although the lunge of a bayonet-fitted rifle in the hands of a powerful man is amply sufficient to drive the blade through the ordinary door, the course of the blade is easily turned just as is the blade of the fencer's foil. A single lunge parried, and a quick lunge in return settles the contest between the untrained and the trained man. There is more difference here than there is between the boxer and the novice, because the latter, if he is strong, can always close and go to wrestling, while closing with a man at the other end of a bayonet-fitted rifle is not so easy.

The sword-bayonet is both a thrusting and a cutting weapon. Naturally the thrusting part of the program is the fatal part, yet a cut of a sharpened bayonet may weaken or demoralize an opponent until he gives ground or falls victim to the lunge.

In the American Army the soldier in bayonet fighting is taught to grip the rifle at the small of the stock or grip with the right hand, and the portion just ahead of the rear sight with the left hand, bolt handle upward, barrel toward the body, bayonet at the height of the chin, left foot extended, body balanced on the feet like that of a boxer on guard.

Bayonet Work in the Army

Teaching the bayonet charge to soldiers.

In regular bayonet technique the thrust is merely a quick drive forward of the rifle, without moving the feet, the butt at the height of the chin, the barrel to the left, the rifle lying on its side. The lunge is the same motion, a slight lifting of the rifle and a drive forward almost horizontally, but here the soldier advances the left foot as he lunges, thus throwing his weight behind the drive.

These two thrusting attacks are supplemented by the right and left cuts, the left

cut, for example, done by slightly drawing the point of the bayonet to the right, then making a slash to the left by quickly extending the arms. The right is the reverse. With the ordinary half-sharp blade this attack is of little importance, but with a sharp bayonet, whetted to a razor edge as the Bulgarians carried theirs, an attack of this sort, ending in a slash across the opponent's arms or hands, might speedily disable him.

The attack with the butt of the rifle, which is merely driven to the front, to the rear by a pivot of the body, or to the left or right, is useful chiefly for rioting, where the bayonet would not be used, or where close quarters did not allow the blade end of the gun to be brought into action.

The defense against these attacks is merely two sets of parries, the right and left, and the right low and left low. In the two, first mentioned, the parries are nothing more than short, quick motions of the left or controlling arm, moving the bayonet point 6 inches or so to the right or left of normal, and so catching the blade of the opponent's rifle. As the rifle on the defense is held firmly between the two hands, with the arms close in and the gun under full control, it is easy to turn off the blade of the enemy rifle which is of course extended at the length of his arms and easily deflected by the firm opposing blade. The whole technique is so very similar to that of boxing when skilfully conducted that it was found that professional boxers excelled as bayonet instructors.

THE TERROR OF "COLD" STEEL

The danger to the tyro is that in parrying he may move his bayonet too far in his anxiety to get the threatening blade as far to one side as possible, lose his chance for a return thrust, and open himself to the real thrust of which the first was only a feint.

The combination of these simple movements makes a dazzling attack and defense in the practice bayonet fighting in the regular service. Anyone who has ever watched these contests between practiced bayonetmen will agree that, as stated, a fight between the trained bayonet fighter and the untrained man is merely slaughter.

In the breasts of many people cold steel arouses a thrill of horror, not inspired by the knowledge of the power and "undodgeability" of a bullet. Doubtless this is why so many positions are evacuated on a bayonet attack without waiting for the final argument.

On the other hand, the bayonet is dangerous just so long as the arms and the rifle will reach, and the danger is always in sight and always avoidable by giving ground or superior skill with the same weapon. The bullet is dangerous, clear to the horizon, cannot be dodged, carries no "if's" and "but's" as to penetration, and, all in all, knowing both bayonet and bullet as well as is possible without actual personal injury, it is safe to say that the preference would be the bayonet to one shot from the rifle.

MAKING THE SHELL FLY TRUE

Some Details About the Rifled Gun, and an Ingenious American Substitute Therefor for Steadying the Flight of Mortar Shells

IF you shoot an arrow without a bunch of feathers at the wrong end, it will play some very funny tricks. It will wobble about in its flight like a man who does not know that there is such a thing as prohibition on the calendar, darting erratically here and there, or even turning completely over in its flight. It will in fact do almost anything except fly straight and true to the mark at which it is shot. The addition of the little tuft at its hindermost end, however, keeps it in its true trajectory, and makes aiming a possibility instead of a hollow mockery.

The arrow is not the only thing that needs a stabilizer. The kite needs one, and gets it, of the same sort as the arrow. And a projec-

tile, be it bullet or shell, spherical or cylindrical with a sharp nose, will wobble and deviate from its calculated path, more and more the greater its velocity, unless something is done to prevent.

It is many years now since the observation was first made that a rotating body is steadier than one that does not rotate. This principle of the gyroscope has found a variety of applications. A top which would not stand up for an instant on its pointed end will stand and spin peacefully for minutes at a time—until the air resistance stops its spinning, in fact. A bicycle will remain upright as long as it has headway. A wheel which can easily be tilted when at rest is forced from its plane of rotation when in motion only with the greatest display of force if at all. And—a bullet or a shell that rotates about its axis of flight flies true, without wobbling. In the case of the shell the long axis, instead of capsizing like the unfeathered arrow, remains in a position of approximate tangency to the path of flight. This fact is the only thing that makes artillery and rifle fighting possible at the high muzzle velocities of today; it is the factor that enables us to aim at a target and be sure we will hit it.

As everybody knows, the projectile is made to rotate in its flight by "rifling" the gun. This means that the inside of the barrel, instead of being smooth, is traversed by spiral ridges and hollows. The ridges bite into the projecticle as it passes down the bore, and it has to follow them in their spiral—in other words, it has to rotate. The shell has such a high linear velocity that a comparatively slight pitch to the rifling gives it a surprising velocity of rotation by the time it gets to the mouth of the gun.

In the smaller caliber guns the rifling has a uniform or "circular" twist of about seven degrees. In the larger calibers the rifling is parabolic, or gradually increasing in pitch—usually from one turn in 50 calibers to one turn in 25. With the mild twist which these figures indicate, the .30-caliber rifle bullet is made to rotate at 150,000 revolutions per minute, the 15-pounder anti-aircraft shell at 25,000, the projectile from the 3-inch field piece at 17,000, and even the large and heavy shells from the guns of high caliber at 4,000 revolutions per minute.

In guns of medium caliber the grooves of the rifling are several hundredths of an inch deep. The bore of the piece is understood to be the inside diameter of the lands or ridges—that is to say, the rifling is thought of as consisting of grooves cut in the gun, rather than as ridges built up on it. A good deal of pressure arises from the fact that the copper driving band which bites into the lands is several hundredths of an inch larger than the space down which it has to travel—in fact, this stress often equals that set up by the gases themselves.

It is interesting to see just how the forces come into play behind the advancing shell. The maximum powder pressure and the maximum linear acceleration occur when the gases have expanded to about 1.8 times their original volume. It must not be understood by those who lack the inclination to mathematics that this means that the projectile slows up after this—we have not said that the maximum velocity is here reached, but merely the maximum acceleration. Acceleration is the rate of increase of the velocity—if you walk at uniform velocity your acceleration is zero. It takes force to produce acceleration—to maintain velocity requires no force save what may be necessary to overcome friction and resistance of the atmosphere—witness Sir Isaac Newton's first dictum. So the shot, provided the powder is well designed, travels faster and faster as it goes down the barrel, but the *rate of increase* of its velocity is greatest about four-fifths of the way down.

The relation between the linear acceleration of the shell in its forward path, and its angular or circular acceleration under the influence of the rifling, depends upon the character of the latter. In guns of uniform rifling the rotational acceleration reaches a maximum before the linear. But the parabolic twist on the face of things makes the velocity of turning increase faster as the shell advances over the more sharply pitched turns of the rifling, and accordingly the circular acceleration has a maximum at the very muzzle, where curiously enough the linear acceleration, though tolerably high, is yet at a minimum. This introduces a queer quirk into shells with a fuse depending upon mechanical action; for it is necessary to consider with extreme accuracy all the factors involved to find whether

the relative rotation (of the fuse mechanism referred to the shell) will take place as desired.

The rifling with the consequent rotation of the shell is introduced to obtain steadiness of flight. In doing this it brings in a new source of error; but fortunately this can be calculated in advance and allowed for, where the motion of a non-rotating projectile is purely at the mercy of chance. The observed fact is that, in the case of "right-handed rifling," the shell, instead of following a path straight ahead from the gun, drifts away to the right, so that to score a hit the aim has to be at a distance to the left of the target which increases with the range.

Now it is customary to say that the rifle-bullet or the shell drifts for the same reason that a pitched ball curves, and to let it go at that. A little thought will make it clear that there is more to it than this. The pitcher curves the ball, or the golfer develops a pull or a slice, by causing the ball to rotate about a vertical axis, an axis perpendicular to the line of flight; a point on the surface of the sphere travels across the advancing face from one side to the other. It is then easy enough to show that on one side the ball rotates against the passing air stream, so that it here encounters greater resistance than on the other side, where it rotates with that stream. Therefore it is forced off its path in the direction toward which it rotates.

The case of the projectile is different. It rotates about its own line of flight as an axis; a point on the front of an advancing shell stays on the front, merely describing a circle about the nose as center. There is no point where air pressure seems to be greater than anywhere else. But such a point exists; for the gyroscopic action of the shell, which keeps its long axis continually turning in the effort to maintain a position parallel to the direction of flight, keeps also the bottom of the shell's front snuggled constantly down into the air that opposes its passage, while it continually pushes the upper surface of the shell's forward face down out of the resisting air. So the shell is brought to roll on the denser bank of air under its nose, and is thus thrown further and further to the right the farther it advances.

As a matter of fact, the complete motion of the projectile is not a simple rolling, but combines this with a gyroscopic "precession," as it is called. The gyroscopic force does not hold the shell absolutely rigid, but leads the point to describe a small circle in its flight—or rather a long spiral, in view of the fact that it *is* in flight. Even the top when it goes to sleep is not absolutely rigid; it too precesses, describing a circle with its apex. In the projectile, this gyroscopic precession combines with the rolling effect already noted to make the shell trace out what may be described as a near-spiral with a series of breaks toward the right. At each of these breaks the path of the shell, if plotted, would show a slight point or cusp; at each its nose is thrown a trifle more to the right than it was before.

If we can calculate the drift—and of course we can—it does not embarrass us in our shooting. But when we have to shoot with a smooth bore gun, as in the case of the mortar, the case is otherwise. Here we get no rotation in our projectile, which is accordingly highly unstable in its flight. Moreover, the trajectory is a very high one, with a very sharp point, which only a highly stable shell could hope to negotiate without tumbling. To be sure, the high trajectory works both ways; if it tumbles, this shell will come down and miss its mark by feet where a shell traveling a flat path, if it tumbled, might miss by a very respectable fraction of a mile. But there is the fact that the mortar is not accurate until we make its shell stable. An effort has occasionally been made to achieve this result by fins on the shell, but this complicates too much the business of firing. And obviously we cannot do it by rifling, because the mortar is not a breech-loader, and we can't force the shell down over the lands from the muzzle. Indeed, in the trench mortars the shell does not get forced down at all; it gets dropped down, and is fired by its own impact with the firing pin when it reaches the bottom, so that the man who puts it in the gun has to get his fingers out of the way in a great hurry if he doesn't want them shot off.

An American investigator has completed the design of a shell for use in mortars, which rotates through application of the turbine principle. His work was completed too late to be of service before the war ended, but appears to be of great value, and is part of the

story of the war because it was the war that impelled him to work on the problem.

The elongated ogival projectile was made in two parts, the one a tough steel rear part chambered out to contain the propellant, the other an aluminum nose provided with a steel plug at the rear for screwing into the steel part of the projectile. The steel plug serves the double purpose of closing the chamber and attaching it to the front part. With the aluminum part in front such projectiles are particularly well calculated for tumbling, and invariably did so when fired in the usual manner. At the extreme rear of the steel part of the projectile a plurality of bell-shaped bores was provided, leading tangentially from the chamber within the projectile to the rear where they emerged into the barrel of the gun. On screwing the aluminum nose with its steel boss into the opening of the chamber the whole presented an appearance of an ordinary elongated projectile except for the bell-mouthed bores visible at the rear. When the gun is fired the propellant within the chamber is ignited by priming contained in the tangential apertures.

The gases thus outflowing through the bell-mouthed bores, while they would give some rotation, owing to their friction within the chamber, would fail to give sufficient rotation if it were not that steel pins are inserted across the chamber to form a sort of baffle, so that the outflowing gases may react against this baffle and so tend more strongly to rotate the projectile.

It was feared that the combustion would not be completed, or at least that the gases would still remain in the chamber at high condensation at the time when the projectile left the muzzle of the gun. If this were the case it might easily be that owing to some slightly unsymmetrical construction of the bell-mouthed bores some tendency to deflect the flight of the projectile would be caused by the delayed outrush of the residue of gases. In order to avoid this, the end of the barrel was continued by a tube extending some 10 inches beyond the former muzzle, and at the rear of the tube where it joined the barrel there were drilled a number of holes so that the gases might escape therefrom and relieve the pressure within the chamber of the projectile while still it was subject to guidance from the lengthened barrel of the gun.

Very satisfactory results have been obtained in firing these special projectiles. This method of securing rotation of projectiles appears to be suitable not only for trench warfare but for all varieties of ordnance larger than one inch in diameter. Results as great as one rotation in 18 calibers have been obtained thereby which, as shown by the figures given above for rifled guns, is more than enough.

The experiments have been conducted within the enclosure of the Astrophysical Observatory, so that it was impracticable to employ heavy charges so as to get very high speeds of flight, but within the range of experiments it was found by shooting through a succession of paper screens and observing the holes with a theodolite that within the length of the observatory enclosure there is no measurable lateral deflection of the projectile while in flight. Truly round holes are always left by the rotating projectiles. Very striking results were obtained in an experiment made in Virginia in the presence of a number of ordnance officers. Two successive shots were fired at a target in one of which the projectile was made to rotate by means of the included charge and in the other of which the projectile was fired by powder outside of itself. In the one an excellent hit was made, leaving a true round hole, while in the other it happened that in the tumbling of the shell in the air it reached the target exactly broadside.

THE INFLUENCE OF THE AIR ON A SHELL

A very interesting but highly complicated mathematical problem is that presented by the atmospheric resistance to a moving projectile. This resistance increases with the velocity, but not directly or in accordance with any simple mathematical law. It is affected by the shape of the shell, so that for every shape there is a coefficient, determined by experiment, which has to be multiplied into the resistance offered to a shell of accepted standard shape. Even the change in the air's density by clear and cloudy weather has its effect, and must be considered in the calculations of the ballistician.

THE SHOTGUN AS A MILITARY WEAPON

How the Spray of Buckshot from the Conventional Shotgun Was Used to Stop Enemy Onrushes

ONE war suggestion that was put through in record time is the shotgun. For experts and soldiers at various times had urged the employment of the repeating shotgun both for our aviators and our infantry, ever since we entered the war; and finally General Pershing's men were equipped with such a weapon which they had ample time to use on the enemy before the armistice called a halt on the fighting.

The new weapon is a comparatively short repeating shotgun of the pump-action type, holding six shells in its magazines. Each shell is of the paper kind such as is used in sporting shotguns, and contains nine pellets of No. 00 buckshot, or about the size of a 32-caliber bullet. When fired the new American gun sprays the contents of each shell over an area measuring nine feet horizontally and about three feet vertically, so that it is almost impossible not to hit a large number of infantrymen coming to the attack in the typical mass formation of the Germans. As for the penetration power of the buckshot, it is said that during one of the early tests the hail of lead went through a two-inch plank with plenty of energy left for further damage, at 150 yards from the muzzle.

One of the problems which had to be solved in adapting the shotgun to military practice was that of the bayonet. The shotgun barrel is quite thin; so much so, in fact, that it would not offer sufficient support for bayonet work. This difficulty was overcome, however, by providing the shotgun barrel with an outer steel coat or jacket which, being perforated and held a short distance away from the barrel proper, so as to form an air space, acts as a cooling member while affording rigid support for the bayonet.

The American Army shotgun weighs 8¾ pounds, complete with bayonet. It is equipped from muzzle to stock with a leather rifle sling so that it may be slung over the neck and shoulder in the manner of the usual rifle.

COMMENTS FROM THE ENEMY—NATURALLY!

The American forces used the shotguns against German raiding parties early in our participation in the war. The Germans suffered heavy casualties as a result, and such survivors as got back to the enemy lines must have made a complete report on the latest Allied atrocity! At any rate, it was not long before the Germans proclaimed to the world, as was their custom, that the American troops had resorted to the barbarous practice of shooting at the attacking Germans with shotguns. It seems unbelievable to hear such a complaint from the inventors of poisonous gas warfare, long-distance bombing of unprotected cities, liquid flame attack, hospital attacks, and so on. Yet, after all has been considered, it runs true to form.

But if there is a good field for the shotgun in repelling land attacks, there is even a far better field in the air, where the chances of hitting a foe with the ordinary machine gun are far less than elsewhere. So the machine shotgun came to be considered in connection with air fighting, although it was never developed to a point where it came in for real service. However, the possibilities of spraying an enemy airman with a rain of leaden pellets from a shotgun were considered quite seriously, and experiments were carried out.

At last the airplane was recognized as being a winged object, and the gun of the wing-shooter was to be used to bring it down. Another prognostication made frequently in the popular press was about to be fulfilled. It was the intention of the Aviation Section of the Signal Corps to give the candidates for flying instruction as much practice as possible with shotgun, rifle and machine gun,

PLENTY OF HITTING POWER AND HITS

At short range—which means at 100 yards or less—the shotgun with buckshot or the largest sized pellets just under this designation, is a more potent weapon than the machine gun. Lacking range and penetration and accuracy because of the spread of its pellets at any serious range, the shotgun, preferably the automatic shotgun, covers more territory at 50 yards or 75 yards than any machine gun, and each discharge throws a cloud of round bullets instead of the highly concentrated, narrow stream of the machine gun. Contrary to common impression, the machine gun is not an all-pervading sort of a weapon. I (the author again is Captain Crossman) stood behind one firing at two man-figure targets at 150 yards. The gun fired two clips of 60 shots for the total without touching either figure, and the figures were handily situated on a hillside which marked by the dustpuff, each shot. Were they in air without a background to show bullet impact, the gun might never have hit them. As we at the side could see, the bullets were striking just over the figures, and the narrow cone at this range was not sufficient to touch them with the slight mislaying of the gun. But, to the crew, the gun was fairly tearing them to bits.

At shorter range the tendency to miss clean with the machine gun is still more marked. Here one bullet fairly follows on the heels of the other; the huge dispersion of the machine gun at longer range, caused by the vibration of the gun, and variation in ammunition, is absent. In effect the weapon is merely the infantry rifle; if the first shot of the burst misses, the next score will also likely miss, until the alignment of the gun is changed by its recoil or by the movement of the plane.

Also the machine gun is not a speedy weapon to handle; some planes have the guns mounted practically integral with the plane and it is necessary to point the plane to point the gun. When the other aviator swoops and comes up close aboard, with the gun pointed off in some other direction, then is the time when a few rapid shots with the automatic shotgun are likely to clean out the opposing plane.

Buckshot is not unlike shrapnel, the chief difference being in the smaller size of the buckshot. The velocity of both is low, buckshot having the best of the argument when used over buckshot ranges, as compared to shrapnel at usual shrapnel distances. Both are round leaden missiles with considerable blow but not much penetration, hence the light steel shrapnel helmets of the French, British, and American troops.

It is this buckshot that would be the logical load for the shotguns of the American aviators. It is not a new man-killing arrangement. For years the sawed-off shotgun has been the favorite weapon of the American really out gunning for the other fellow or expecting the other fellow to come a-gunning for him. The sawed-off part of the contract is merely to get rid of the choked portion of the barrels at the muzzle and so let it handle buckshot better, and to make the gun shorter and easier to swing. At revolver ranges no more fearful weapon was ever put into the hands of man. It is far more accurate than the revolver, while its dozen or so round bullets make hitting nearly sure with any sort of pointing.

THE SHOTGUN AS A WEAPON OF LONG STANDING

Sentries of our Army have been for years armed with riot guns for certain guard duty —a riot gun being merely a repeating or automatic shotgun shooting buckshot. Express messengers and guards of other sorts of treasure pin their faith to the short shotgun on the brackets close to hand.

When it comes to a choice among shotguns, there can be but one decision. The automatic or self-loading shotgun is of much greater speed than the pump variety in the hands of the average man, is more positive in function and there is practically no disturbance in the aim between shots, because neither hand has to be moved, and the recoil is translated into more of a push than a blow. There is no difficulty in firing five shots through the automatic shotgun in about two seconds.

Buckshot ranges in size from nine to twenty-seven to the ounce. The writer recently put a few loads of No. 1 Buck through

their paces to see what might be expected of this quite average load.

The cartridge contained 1¼ drams of bulk shotgun smokeless and 12 No. 1 Buck, or one ounce. The muzzle velocity was probably about 1,300 feet per second. At 90 feet—using a choke-bore gun—eleven shots out of the twelve hit the man-sized figure, the eleven grouping amidships and close together. They would have meant instant death, as is quite clear from their grouping. At 150 feet, seven pellets out of the twelve hit the figure, which included only the body from the waist up, with the head and neck outline. At 300 feet, because of the difficulty of aiming straight enough to center the load at this range, the greater part of the pellets went to the left, and the first load missed the figure. The second and third loads hit the figure with two shots each, enough instantly to knock out the victim. At this distance the buckshot galloped through 1½ inches of redwood, which is ordinarily an ample penetration.

At the 90-foot range the gun threw a cloud of shot about 18 inches across, barring the one wild pellet. At 150 feet the spread was about five feet, and at 300 feet 10 or 12. Beyond 100 yards the spread of the load was too great to ensure hitting, although it was still extremely dangerous for such a mark as an airship with two men and the delicate parts of the craft. Under 100 yards a well aimed load of buckshot of the size used would be nearly certain to wing if not entirely to disable the pilot of the ship. The No. 1 Buck is just .30-caliber and weighs 40 grains.

MINIATURE SHRAPNEL AND ITS PROBABLE EFFECTS ON AIRCRAFT

Turning to the use of the shotgun brings up once more the question of using round ball in cases where great penetration and a knockout punch are desired. The writer has done much experimenting with round ball in the shotgun, and he is under the impression from these experiments that the huge round ball of 500 grains or more weight, and .70-caliber, would under certain conditions wreck an airplane or knock out the pilot more quickly than a whole stream of machine gun bullets. Five rapid shots from an automatic shotgun loaded with round ball, under 100 yards or so, would prove astonishingly effective, in view of the huge weight and the enormous blow delivered by such a bullet. While its energy is actually less than that of the rifle bullet, because of its great diameter and its tendency to flatten, it delivers its entire blow, where the rifle bullet merely whips through, doing no more than bore a hole.

DEVELOPMENT OF THE ARMY PISTOL

How the All-Important Stopping-Power Requisite Has Resulted in the Adoption of Larger Calibers

IN the hands of the average man the pistol is perhaps most formidable when thrown at the enemy. Not that the penetration or the lethal qualities of the arm are greatest when used in this way, but the chances for hitting overshadow all other considerations.

Yet accuracy with the pistol increases wonderfully with the slightest practice. This fact is proved by the inability of beginner after beginner to hit a washtub at 10 feet in the start of things, and the later consistent holding of the 8-inch bullseye at 150 feet when the idea of yanking the trigger has been abandoned after sad experience.

With the war degenerated into a desperate struggle at short range for the possession of very undesirable sets of mud-holes, the pistol came into a field of usefulness from the military standpoint which it has not occupied since cavalry fights were the proper thing.

A large calibered automatic pistol fired at a gentleman jabbing at you with a hungry-

looking bayonet in the endeavor to make you share your trench with him, is very likely to abate the nuisance.

WHEN RIFLE AND BAYONET ARE CLUMSY

In the mêlée the rifle is too long to be used with the best effect, and a bayonet is no better than its own length plus that of the rifle which holds it. There is no doubt as to just what a bayonet can do. But the ten-shot automatic pistol fired by a fair pistol shot at attackers at close range, is considered more efficient than the rifle because the time is too short and the rifle too long. Six feet of range terminates the usefulness of the rifle, save as the accompaniment to the bayonet, while, on the other hand, the pistol can be used up to the last gasp, and even should the combat become a hand-to-hand struggle the pistol can still be brought into play with decisive results.

Ordinarily, the author is a scant believer in the efficacy of the pistol, this through considerable experience with one in target shooting and in trying to hit things when he really felt considerably interested in hitting them. Yet, when the problem is merely one of killing as many men in as short a time as possible, and when the range and the mark make missing almost as difficult as hitting, there is no discounting the superior efficacy of the well-handled pistol. Its high rate of fire, its speedy recharging, the small space needed in which to use it, and the fact that until needed it can be out of sight and out of mind and still instantly accessible, all go to make it a very desirable adjunct to the equipment of the trench-fighting infantryman.

There is no disputing the superior efficiency of the large-caliber pistol as compared to the smaller. The modern automatic pistol uses metal-jacketed bullets because of the more certain functioning of the smooth, hard bullet. The velocity of the pistol is so low that no attempt to make these bullets mushroom will succeed; there is insufficient weight and speed to make them burst open the jacket.

Because of the proved lack of immediate lethal qualities in the small-caliber pistol bullet, and the very urgent need of them in all cases where the pistol can be used with success, the large calibers are the only satisfactory ones. If it is not possible to make a pistol bullet, wrapped snugly in a tough skin of cupro-nickel or sheet steel, flatten similarly to a lead bullet or mushroom like a game bullet, the only recourse is to use as large a bullet as possible, and accordingly make the resulting perforation as generous as possible.

WANTED: AN ABSOLUTE MEANS OF STOPPING THE CHARGING FOE

It is obvious that the main function of the pistol is to dispose immediately of an antagonist before he can do harm to the possessor of the weapon. In his ultimate fate you have little interest if you are killed or in a hospital yourself. It is far better to eliminate the foe as a fighting force, even temporarily, than to inflict a fatal wound—fatal hours later but still not immediately disabling. In stopping a man with a pistol, time is the essence of the contract; it is what the other man does the first ten seconds after being hit that determines whether or not the arm is an efficient one.

Owing to the absolute necessity of immediately eliminating the foe—delivering the crumpling blow of the bullet on one who may be threatening the possessor of the pistol with almost certain death—the United States Government has adopted the .45-caliber with a ponderous 230-grain bullet. The velocity is but 800 feet per second, less than a third that of the army rifle, while the bullet weighs 50 per cent. more than that of the rifle. Range, flatness of trajectory, remaining energy at a mile—none of these things count when the mark is but a few feet away.

BIG CALIBER REVOLVERS WHERE CHANCES CANNOT BE TAKEN

Those nations having dealings, friendly and otherwise, with savage folks, become strangely enamored of large-calibered pistols. The British, after various dealings with the hill men of India, who consider it manners to rush a camp with curved knives of razor sharpness, evolved a generous bullet of .455 diameter, heavy, and of low velocity for their service revolvers. Their officers went even further, and adopted a double-barrel pistol taking either huge slugs or else a number of

buckshot. These pistols were usually 20-gauge in shotgun measurement, which in inches is .615-caliber, smooth bored, very often with hammerless ejector and single trigger not unlike the most improved shotgun. When the two barrels were fired and the two huge .61-caliber slugs went on their way, there was usually a very pleasing vacancy in front of the gun.

The United States Army abandoned the old single action .45-caliber revolver in the 90's, and adopted a .39-caliber double action revolver. Then came the conquest of the Filipino insurgents, in which the revolver as a weapon was largely employed. The experience of the American soldiers engaged in the conquest was precisely that of the British—namely, the larger the caliber the better the immediate results, which in revolver fighting are the only ones of account. The .38-caliber was voted ineffective, and this gun, like all revolvers, had a pure lead bullet, which would mushroom or flatten quite readily, and which the bullets from the automatic pistols will not do at all.

So there is considerable satisfaction with the revolver of the American forces, the .45 automatic pistol of Browning patent, with its eight shots, its compact form, ease of taking apart, and certainty of function—and the terrific "wallop" that it deals.

The other nations, lacking the practical experience of the Americans along a western frontier, and that of the British in their various and never-ceasing arguments along the Indian frontier, favored smaller calibers in their pistols than we regarded as being practical. The 9 mm. or .36-caliber appealed to them as being enough cartridge for anybody.

The Germans divided their choice between the .30 Luger and the .30 Mauser; the Austrians used the Mannlicher pistol; the French the revolver of .38 caliber; the Spanish, the Swedes, and to some extent the Belgians used the Bayard pistol of 9 mm. or .36 caliber.

None of the nations engaged in the war had adopted the .45-caliber in its automatic pistols, but doubtless they will know better if they ever go to war again.

WHEN MARS TURNS BACK THE CLOCK OF THE CENTURIES

How Hand Grenades and Liquid Fire, Weapons Obsolete Since the Invention of Cannon, Were Revived and Used Effectively

As has been shown in the preceding chapters, the functions of the big gun and of the rifle are wholly different. The former is for use against positions (and incidentally against men) at a distance; the latter finds its employment when it is necessary to operate against men close by. But this leaves a gap; what are we to employ against positions at short range? The problem thus stated is not altogether a new one; for the mortar, a gun of high angle and low muzzle velocity, is devised for the very purpose of throwing shot and shell into fortifications which lie so close to our own positions that we cannot profitably bombard them with regular guns.

But the trench warfare which came in in 1914, and lasted until the Germans were finally rooted out of the ground by the tank and the superiority of numbers, introduced a situation which was new, and which was not satisfactorily met, even by the mortar. Never before in the history of warfare had it been the case that forts fought with forts. A trench is perhaps not much of a fort, as forts go; but when you lay down two lines of opposing trenches within less than a hundred yards of each other, you have the condition which is described by the words "forts fighting with forts." And the range of the mortar, short as it is, is still far too great to permit the occupants of one of these trenches to use it against the other.

The answer to this problem of how to operate against the hostile trench from your own front line cannot lie in any gun. Neither can it lie in any rifle, for the rifle is effective only when the occupants of the hostile trench show themselves above the ground level. But some ingenious soul took note of the fact that for the most part the distance across No Man's Land was no more than a man could throw; and with this observation the hand grenade was reborn.

Of all surprising features of the great war, few rank higher than this reversion to the methods of four hundred years ago. Who could have believed that, in an age where the range and power of guns and explosives was ever on the upward path, a state of affairs could possibly arise where the armies of two first-class powers would find it profitable to fight largely by throwing things at one another after the fashion of their antediluvian ancestors? Who could have restrained a jeer at the suggestion that the human arm would to such a large extent supersede the firearm? Yet this is the thing that happened.

THE HAND GRENADE

Once more it was the Germans who were responsible for an innovation; and, indeed, here as elsewhere, they seem to have figured the thing out in advance, for they were well supplied with grenades from the moment when they entrenched after the Marne. The Allies were quite unprepared for this sort of thing, and until they could get manufacture under way they were restricted to home-made grenades made by filling explosives and bits of metal into tin cans. With the passage of time and the development of the technique of trench fighting, the grenades were greatly improved on both sides, and special types created for special service; and of course here as everywhere else, after the Allies had once paid the price of their initial unpreparedness, their methods and their equipment were well up to the level of those of the Germans.

The first thing to note in the use of grenades is that it makes a difference whether they are to be thrown from well sheltered places or not. In the first case they may be as powerful as we wish; in the second we must be sure not to make them so heavy that the thrower will feel the effects of the explosion. For the grenade is not merely a bullet or a slug of metal, thrown over the lines with the intent of knocking out one of the foe by a direct hit; it is in every respect

Courtesy of Scientific American.

An Idea Borrowed from the Warfare of Long Ago

In the early days of the great war, before the Allies had trench mortars, the soldiers themselves constructed crude cross-bows and catapults, such as the one here shown. These were employed for hurling grenades into the German lines.

a high explosive shell save in the manner of its launching.

No particular description need therefore be given of the grenade *per se,* except to point out that the firing mechanism must be specially designed for the purpose in hand. If the grenade does not explode at once, somebody is going to pick it up, or even catch it on the fly, and hurl it back whence it came. On the other hand, there is no inertia of any

account in connection with its delivery, and there is no mechanical device like a pin or a lever to be touched in connection with throwing it. You just take it in the hand and throw it away, and that is all there is to it. So there is no avoiding the necessity of having some kind of a firing mechanism to be directly operated by the thrower just before he throws it. And then of course he has to get it away at once and without failure, or it will go off in his hand. Most of the grenades are set off by a short fuse which in turn is fired by a percussion cap. The firing pin is held off this cap by a safety pin; and the act performed by the thrower consists in the removal of the latter. The fuse is fired while the implement is still in his hand, and he throws it with this sputtering.

BASEBALL VS. GRENADING

There is a certain science in throwing the grenade, as any American who thought it was purely a matter of baseball will gladly testify. The baseball weighs but a few ounces, the grenade as much as two pounds; and if you start pitching grenades with the same free motion used by a pitcher or an outfielder, you are going to have a mighty lame "wing" in very short order. You might as well try to put the shot with the same motion used in throwing a baseball, as to introduce that motion into the business of grenading. In fact, as the French instructors tried to impress upon the doughboy, the grenade is to be tossed with a stiff arm, the motion being entirely a circular one about the shoulder. If a Boche is coming at you across open ground and you happen to have a grenade handy, you may perhaps gain in accuracy by using your elbow to throw it at him on a line; but in trench warfare the grenade must be flung into the hostile trenches as outlined.

The original grenade was just a shrapnel or high explosive shell, without any trimmings. But as the value of this style of warfare became more thoroughly established, the grenade was used to deliver gas of the various sorts, smoke clouds, etc., as well as to start fires in the other fellow's quarters. In fact, the grenade was found available for every specialized use that was made of artillery.

Nor was grenading abandoned when the trenches were separated by a distance over which the grenade could not be thrown. A good many of us, as youngsters, have hurled a bit of putty or clay to a prodigious distance by impaling it on the end of a stick and sweeping the latter over the shoulder with a snap. The principle, of course, is that of the sling. A grenade cannot conveniently be thrown with a sling, because of the long (and uncertain) time which it takes to place a projectile in the sling and deliver it. The grenade can, however, be given a long handle and thrown with the additional leverage thus gained; and this was actually done on both sides when the desired range was such as to warrant. Ordinarily the handle was not retained in the hand, but was fixed into the grenade, and travelled with the latter; and streamers or tails of one sort or another were then in order to keep the thing head on. It was then even possible to provide the grenade with a percussion cap to be exploded on striking the target.

The long-handled grenade is pretty bulky to store, however, and the man who throws it has got to have a good deal more of the trench for his swing than it is convenient to give him. The answer to these objections was of course a grenade to be shot from the rifle, by the discharge of a blank cartridge. The general principle of this corresponds with that of the rifle light, discussed elsewhere. Weighing many times as much as the service bullet, the grenade would be projected with a much lower initial velocity, and would strike its mark at ranges up to four hundred yards or so.

LIQUID FIRE

Another reversion to barbaric days which was employed more or less on both sides was the device known usually by its elegant German name of *flammenwerfer* (flame thrower). In a word, this is a metallic hose that squirts liquid fire upon the foe. The Germans introduced it with the idea that it would be of considerable general utility; but it was found that its chief value was in the cleaning out of captured dugouts. It was quite customary, when a position was taken, for a certain number of the former occupants to remain in concealed underground ramifications of the

trench system, with the idea of doing what damage they could by attacking the advancing foe from behind; but when the mopping-up squads began sweeping out the captured positions with a broom of fire, the practice became less general and less effective.

The *flammenwerfer* does not require very extended description. It is a metallic nozzle, connected by flexible metallic hose with a tank in which is stored some highly combustible fluid; and of course a pump is provided. Ordinarily the stream is turned on the enemy first, and then ignited—not at the base of the column of liquid, but at the end where it strikes. The rather ingenious means by which this is accomplished is a second and much smaller stream of the same liquid. This is turned on, at the same time as the first, but from a point several yards away; it is then lighted at its base, and when the flame has spread to the business end, it is made to intersect the big stream, which promptly takes fire from it. The flame then spreads down the big stream to the far end, but is not able to communicate back against the flow toward the nozzle. The small stream, which lacks this safety factor, is turned off as soon as it has ignited the big one. The result of all this is a spray of liquid fire which lasts until the tank is empty, and from which the man handling the nozzle is quite safe.

Beating Out the Deadly Fumes

Gas training consisted in spreading the gas alarm, adjusting and wearing the respirator. The above picture shows American soldiers with their gas-masks on and beating the gas out of the trenches.

By J. F. Bouchor

Watching Long-range Bombardment in the Vosges

PART II. THE WAR ON THE LAND

THE TRENCHES

The Development from the Early Crude Ditches to the Elaborate Underground Colonies Which Proved the Downfall of the German Army

THE first few months of the war were devoted to open warfare, to be sure. Large forces of men advanced across open country and rolled back the enemy except at such places as he was present in sufficient strength to give battle. And such battles generally lasted but a short while, and with one side defeated, the other side simply pushed on again. In truth, it was the war of movement.

WHY SOLDIERS DIG TRENCHES

But the high efficiency of modern artillery fire, its long range and accuracy, served to bring about a complete change in the art of defensive warfare, especially in devising protection for troops exposed to such attacks. When we consider the destructive force of a single high-explosive shell and the number of shell which an enemy can now concentrate on a given point, we can readily appreciate that the defender must either invent some means of protecting his men from this fire, or suffer unheard-of losses. And it was this question which drove all fighting forces to trenches, after the war was but a few months old. The trenches which thus became the seat of the war may be grouped into three main classifications:

(1) *Fire Trench,* which is a deep and narrow trench with the parapet flat and concealed. The troops fire from this trench on the enemy.

(2) *Cover Trenches* are the trenches where the supporting troops sleep and live, hence they are covered over to provide protection against the elements, as well as high-angle artillery fire. The cover trenches are placed as near the fire trenches as possible.

(3) *Communicating Trenches,* which are the trenches running at right angles to the fire and cover trenches, and used to connect them with the rear, are usually deep and narrow, so that the men passing through them are protected against rifle and machine-gun fire. They are zigzagged to escape being enfiladed, which means to prevent one explosion from doing too much damage in a single trench.

In solving the problem of protection against intense artillery fire the Germans devised what they were pleased to call the catacombs of war—deep underground trenches which sheltered the men from the elements and hostile artillery fire. According to Mr. Albert K. Dawson, an American correspondent who had every facility to study the war from inside the German and Austrian lines, writing in the *Scientific American,* the idea probably did not originate with the Germans. From his own observations in the beginning of the war, he found the defensive works of the Russians to be superior to those of the Germans, while those of the French and British were far inferior. We quote Mr. Dawson extensively:

THE RUSSIANS AND THEIR WONDERFUL TRENCHES

"At the beginning of the war, the Germans had the preponderance of artillery and the Russians *must* seek cover or be wiped out. Then, too, the Russian brought with him the experience of the long, hard campaign against the Japanese. The first underground quarters I saw, other than a dugout in the side of a bank, were in Poland in the spring of 1915. Here in the outerworks around Ivangarod the Germans found underground positions which made their staff officers sit up with

surprise and admiration. I visited several of these underground camps with an officer of engineers who was making maps and drawings. Many of the German staff came out to inspect them as well, and were loud in their praise of the work of the Russians.

"The Russian trench nearly always had a protection overhead for the soldier. The Germans and Austrians did not have this then, but later adopted it. This protection usually took the general form of a pitched wooden roof. This roof not only offered sure protection from shrapnel and bullets, but it gave a feeling of protection from heavier projectiles. The man had a feeling of security here which he did not have with the open top. The machine-gun positions were always heavily protected and shored up with the strongest timber; for they were always the target for the enemy's artillery. In many of these I saw the long, dark firing aperture fitted with a burlap curtain painted green to match the embankment; for this long, dark slit was easily spotted by the enemy observers. The machine-gun positions either occupied a projecting corner of the line or extended out from the line, much like the flanking towers of a castle.

THE OMNIPRESENT BARBED-WIRE ENTANGLEMENTS

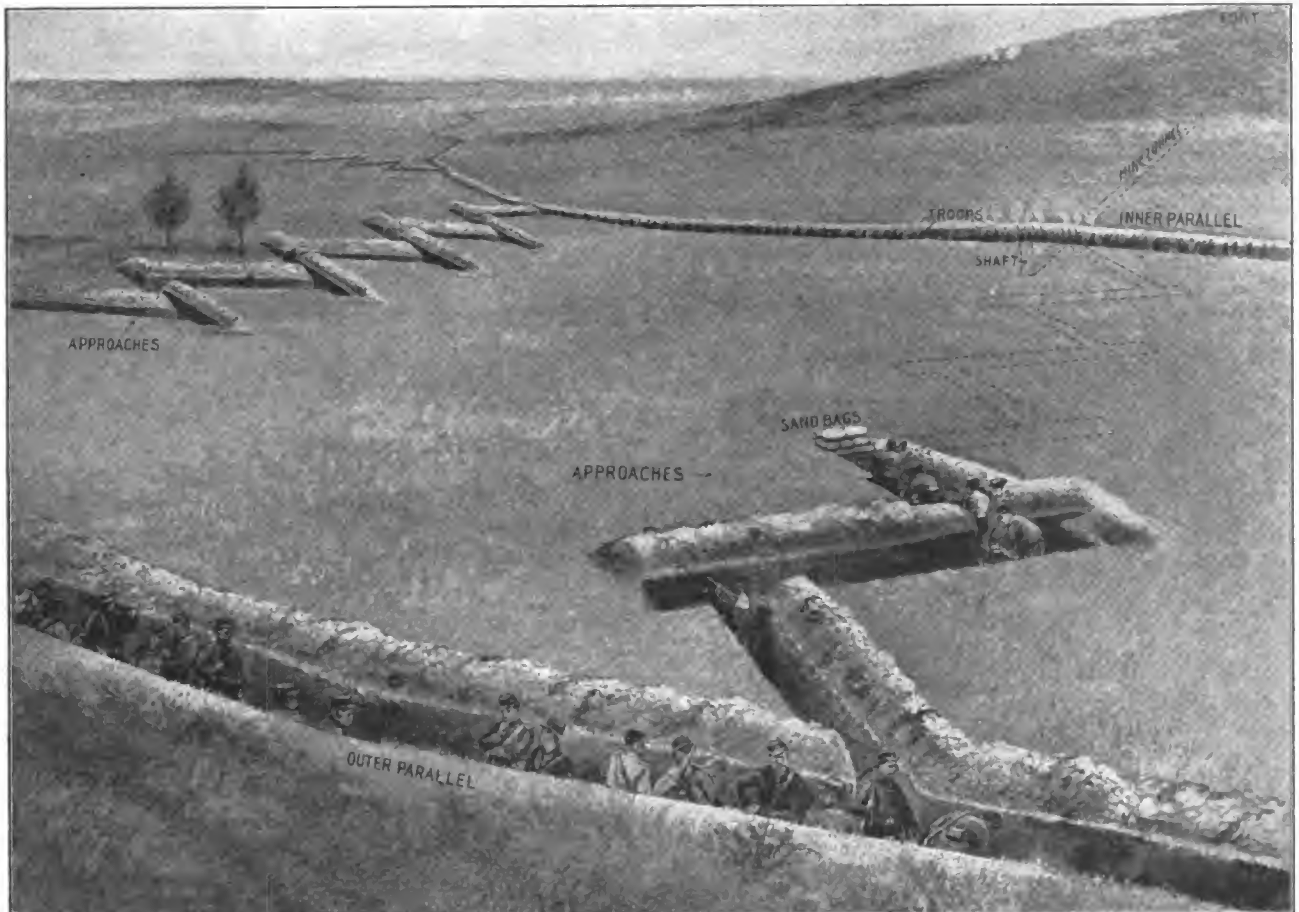
"Beyond the trench we found the barbed-wire entanglements, always one and sometimes two zones of wire. In case there were two bands of wire one was placed directly in front of the trench at an even distance of about ten yards and the other was much farther out in front and zigzagged back and forth. The idea of the zigzag was to create lanes which would bunch the charging enemy and lead him into the angle just before the machine guns. An entanglement consisted of from three to twenty parallel rows of posts with the wire woven every which way among them. To these wires a lot of empty tin cans were often tied, each can containing a stone. These served as alarms. Did any one start to cut a way through in the night, the rattle of the cans soon gave him away. No invention of man proved such a perfect defense as the humble barbed wire, originally intended for no more warlike purpose than keeping cows in a pasture. Moats, abattis, wolf hole and other forms of defense gave way to it. I have seen entanglements where I know men had charged through, and I shudder to think of the punishment they received, and I have peeped through the loopholes to where grim forms hung contorted in the entanglement where the last charge broke as a wave breaks on the shore.

UNDERGROUND BARRACKS BEHIND RUSSIAN TRENCHES

"At favored points behind the well-constructed Russian trenches we found the underground barracks. These were large enough to shelter from 200 to 400 men, packed in rather tight it is true, and strong enough to protect the occupants from fire from all but the very heaviest shells. On the roof we found from ten to twenty feet of earth with the sod put back in place to hide the location from spying airplanes. Usually, these barracks were built in pairs with a connecting tunnel, each with an exit to the covered trenches and an emergency exit. Inside we found a corridor with a double row of sleeping platforms on each side and in the middle a brazier for a charcoal fire. A ventilating shaft was found at each end equipped with heavy shutter, and sand sacks for protection. In some were covered latrines branching off from the connecting tunnel. None of these underground barracks appeared to be permanent dwelling places, but emergency cellars in case of shell fire.

"The material used was heavy logs for overhead timbering, sawed lumber for shoring up and loose earth for cover. Sand sacks were used to build up around the openings. The old type fortifications of reinforced concrete and masonry was found to be worth very little in modern warfare. First, they had to be prepared long in advance, so that their location became known to the enemy, and second, it seemed the more solid and compact the material used the greater the havoc wrought by the high explosive shells. Loose earth was found to give the best shelter.

"The Germans were quick to adopt this underground camp idea and a few months later on the West Front, I found them already turning the abandoned mines, chalk caves and quarries of that section to their use. These



© *Scientific American.*

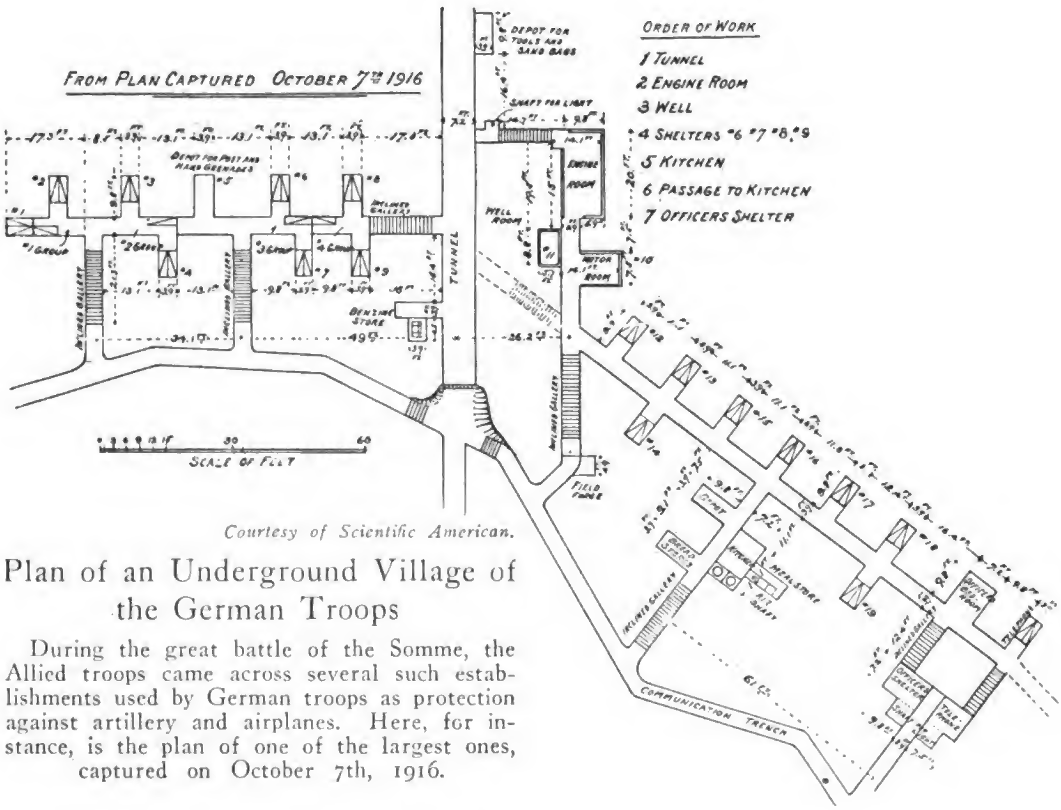
Trenches and Mining Operations in Modern Trench Warfare

In reducing forts, the attackers generally worked their way forward by a series of zigzag trenches. Thus if the fort defenders landed a shell on the trench system of the attackers, the damage inflicted was very local. Meanwhile, shafts were pushed under the surface and toward the fort.

caves made fine shelters for the men, being absolutely secure from bombardment, dry and of an even agreeable temperature. I visited one cave sheltering then 3,000 men. They had a blower-fan ventilating system, operated by hand, and were then installing electric lights. They were also cutting two extra exits to the outside world to prevent their being entombed by a well directed shot from the enemy. This was the largest single unit style and constantly ready for soldiers, would split Europe into three parts. With this idea in mind we can see why the Germans toiled so mightily.

UNDERGROUND VILLAGES FOR GERMANY'S FIGHTING MEN

The accompanying diagram of captured German underground labyrinths gives some



Courtesy of Scientific American.

Plan of an Underground Village of the German Troops

During the great battle of the Somme, the Allied troops came across several such establishments used by German troops as protection against artillery and airplanes. Here, for instance, is the plan of one of the largest ones, captured on October 7th, 1916.

I found underground. The usual underground village held fewer men."

The Germans may have intended their field works in the West to serve as the boundaries for their new Empire, judging from their permanence. This theory is given color by a book, *Mittel Europa* by Friederich Nauman, published in Germany while that country was still in buoyant hopes. In this he says, "The future Europe will contain a system of Chinese or Roman walls made of barbed wire and earth, and stretching from the lower Rhine to the Alps, and from the Baltic to the Black Sea." According to this author these huge trench frontiers, built in the most impregnable idea of the very elaborate manner in which they were constructed and the care with which they were fitted up. The survey of this labyrinth was made by the Germans themselves and fell into British hands when the position was captured.

The following is quoted from a letter written home by a British officer, comparing German front line trenches with their own:

"In standing in the middle of what was a few weeks ago No Man's Land and comparing the German front line trenches with our own, we notice first the more permanent character of their barbed wire entanglements. While ours are supported on wooden stakes of whatever

Modern Intrenched Defenses as Constructed on the Eastern Front by the Russians

It is said that the Germans learned a great deal from the Russians when it came to trenches; and the Russians, in turn, had the Japanese to thank for their trench technique. The Japanese developed trench warfare to a high degree during the Russo-Japanese War.

size and shape is found at hand, theirs is supported by iron rods made for that purpose and of the best possible design. Inside the two trenches the differences are still greater. The Allies' trenches look in every way as if they were made by men who hoped and expected to move on before long. The German trenches look like the work of men who expected to remain in this position for years.

"Our trench housing has been more of a makeshift, a sort of camping out, with some ingenious provisions for shelter and comfort, but not more than the least that would serve. Most of our dugouts are just roughly delved holes in the earth with only enough props and rafters to hold the roof up, while the floors are bare ground with a little straw; their doors, if they have any, are a few odd pieces of plank with a couple of other pieces nailed across. We usually have the floor on the trench level to save burrowing. Lighting is done with candles, mostly bought out of our own pocket at the canteen, and if any one owns an armchair or a mirror it is the jest of the platoon.

"The German front in the west is like one huge straggling village strung out along a single street of 300 miles. Of course the houses are all underground, still they are houses usually of one or two floors built to certain official designs which are drawn out in section and plan. The main entrance from the trench level is had through a steel door of a standard pattern, so that hundreds may come from a factory on one order and missing parts be easily replaced. The profusely timbered doorway is made to their measure. Outside this front door you will find a perforated sheet of metal to act as a doormat or scraper. Inside a flight of 12 to 36 steps leads down at an easy angle. . . . A tunneled corridor runs straight forward for anything up to 50 yards and from it open minor passages and rooms on each side. In many dugouts a second staircase or two may lead to lower floors 30 or 40 feet below the trench level as shown in the accompanying illustration. All these staircases, passages and rooms are, in the better specimens, completely lined with wood, and as fully strengthened and supported as the entrance staircase already described. In one typical dugout each section of a platoon has its allotted place for messing and sleeping, its own place for parade in a passage and its own emergency exit to the trenches. In another, used as a dressing station, there are beds for 32 patients and a fair-sized operating room. A third near Mametz was designed to house a whole company of 300 men with necessary kitchens, provision and munition store rooms; a well, a machine shop and forge, engine-room and motor-room. Many of the captured German dugouts are thus lighted with electricity.

"In the officers' quarters we found full length mirrors, comfortable bedsteads, cushioned armchairs, pictures and books. One room was lined with glazed 'sanitary' wall paper and the present English occupant is convinced by circumstantial evidence that his predecessor lived there with his wife and child. Clearly, there was no expectation of an early move. . . .

WHERE SAFETY LED TO GREATER DANGER

"German trench work is therefore more elaborate than ours, but that does not mean that it is better. No doubt the size and overhead strength of German dugouts keep down casualties under bombardment and sometimes enable the Germans to bring up unsuspected forces to harass our men in the rear with machine-gun and rifle fire when a charge has carried us past a dugout of this kind. On the other hand when an Allied advance is made good, every man left behind in such a dugout is either a dead man or a prisoner. No doubt, again, the German trenches give more protection in very bad weather than ours. But they also remove men more from the open air and there is nothing to show that the half buried German army gains more by relative immunity from rheumatism and bronchitis than it loses in the way of general health and vitality."

The following is taken from description by W. B. Thomas, of the London *Times*, of some of the German trenches captured in the Somme fight.

"Before describing the battle (Somme fight near Grandcourt and Miraumont) I must say something of the battlefield; one of the strangest, thorniest and most novel in history. The men who stormed the positions north of the river might have been advancing over roofs in a street fight. Underneath them were rooms upon rooms containing hidden and unsuspected groups of the enemy. The battlefield is still unsearched and unplumbed. Pockets of men, stores of material and reserves of ammunition lie hidden here, there and everywhere. The scale of these hiding-placs is on the scale of a town of many streets and well-cleared houses. The trenches themselves are as tangled as the pattern of frost flowers on the window and the maze of crooked lines interspersed with dugout holes extends to a breadth of over a mile.

A section of ground cut through Oxford Street would hardly be more intricate. The crowning marvel of German defense construction lies just across the Ancre (river) on the south side.

"If you slip along the river road you come to an opening about seven feet high in the clay cliff and when you have penetrated into this secret place you find a new world—a Monte Cristo world. Even the guns which thundered to madness outside are blurred to a murmur or are wholly inaudible. A sickly reek pervades the place, though not the reek of dead bodies. A few wounded men, vainly seeking shelter from the battle, lie where they have fallen in the passage.

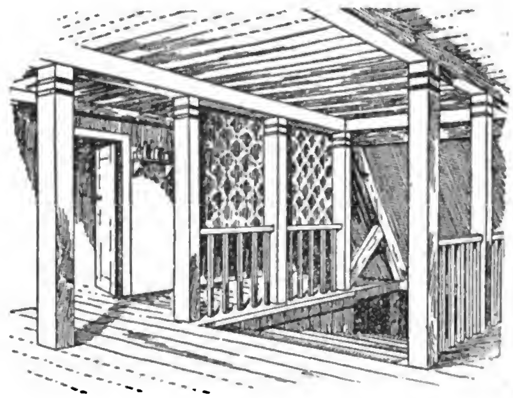
"Those who first walk into this cavern have no other thoughts than curiosity or apprehension. We walk into the unknown, on and on, round one traverse into another, until the broad corridor, 7 feet high and as much in width, is cut by another of like sort leading right and left. The leg of this T-shaped avenue is about 300 yards and the arms—not yet fully explored—are at least 200. Double bedrooms and chambers of various sizes lead off from the corridor, some are papered, all are lit with electricity and the upholstery is sufficient. Paneling is frequent. How many men this barracks would house I do not know, but over 400 prisoners filed meekly out and surrendered after the fight was over. The place was used as a storehouse as well as a barracks, as we know from having found many machine guns and other trench weapons."

This last touch coming from the letter of a French soldier, is worthy of a Jules Verne:

"In really up-to-date trenches you will find kitchens, dining-rooms, bedrooms and even tables. One regiment has first-class cow sheds. One day a whimsical *piou-piou* finding a cow wandering about in the danger zone, had the bright idea of finding shelter for her in the trenches. The example was quickly followed by his comrades and at this moment the Infantry possesses an underground farm in which fat kine, well cared for, are giving such quantities of milk that butter is being regularly distributed; good butter, too."

FROM THE RIGID DEFENSES TO THE FLEXIBLE

Trench systems were steadily improved. The Germans learned much from the Russians, who in turn were putting their Russo-Japanese War experience to good account. And the Allies in turn learned much from the Germans. From plain ditches the trenches became drained and reinforced earthworks, provided at intervals with suitable underground shelters or bombproofs. Behind the front-line trenches were the second-line, and behind the second-line trenches the third-line, or support trenches. And from a safe distance in the rear one passed through long zigzagging communication trenches in order to reach the actual trenches, but it never was safe to expose so much as a hair above the ground for fear of attracting hostile bullets or shell. But these elaborate systems had one serious drawback.



Courtesy of Scientific American.

Hallway of Subterranean Dwelling

A shell does not have to hit square and fair on a dugout to account for its occupants. Indeed, the shell, if it be of large caliber, say 15-inch, can hit several hundred feet away and still prove fatal. The force of the shock spreads in all directions through the earth for a considerable distance, and wherever there are hollows in the earth, such as a dugout, the force exerts itself at those points, the tendency being to collapse the dugouts. So it follows that the heavy British and French artillery fire accounted for numerous German dugouts.

Leaving shell fire aside, the German dugouts were dangerous in that the occupants were generally trapped by the advancing Allies. In order to escape bombardment the Germans had to seek shelter in the deepest dugouts, and when the barrage had passed over, the occupants, endeavoring to come out.

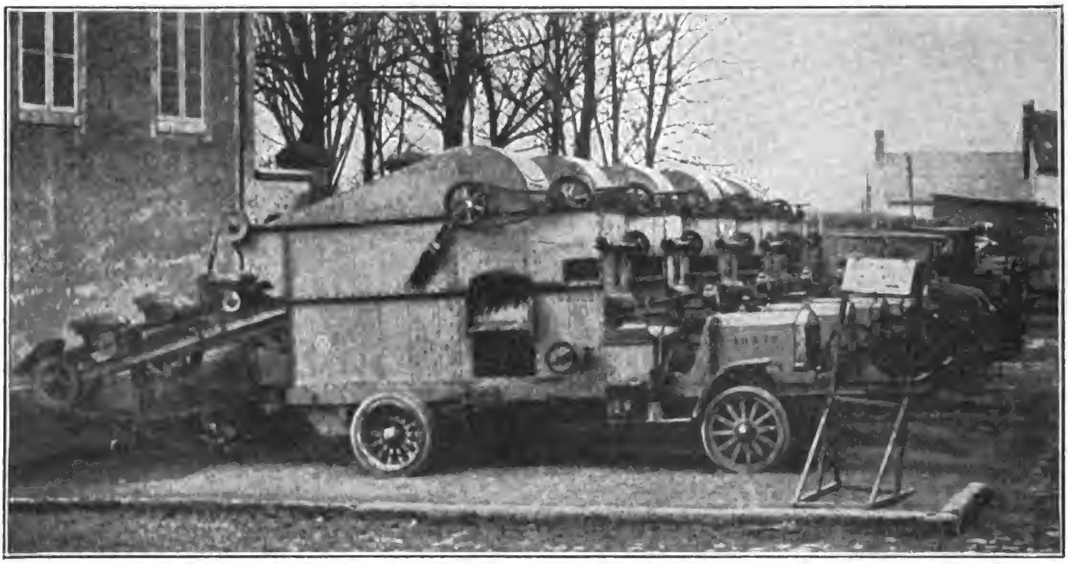
were surprised by Allied infantrymen. Thus the British and French made vast hauls of prisoners during the Somme advance because of the many pockets in which the Germans had placed themselves, beyond the slightest hope of escape.

Because of these and other disadvantages suffered by them while making use of deep underground shelters and trenches, the Germans early in 1917 decided upon a new and novel method of defense, often referred to as a flexible defensive system or a defense in depth. Instead of placing their main reliance on trenches and dugouts, the Germans turned to small concrete blockhouses scattered over a wide area and so arranged that cross machine-gun fire could be brought to bear on advancing infantry. These diminutive blockhouses were soon given the descriptive name of "pill-boxes," and figured in the British attacks throughout the fighting of 1917 in Flanders fields. The pill-box was a small, round structure, with room for one or two machine guns and their crews. Some blockhouses were considerably larger and contained numerous machine guns and men.

THE PILL-BOXES OF THE GERMANS

The pill-box defensive tactics comprised the use of shell holes, trees, rocks, and every other available shelter for machine guns, instead of the old-style rows of trenches which were such excellent targets for artillery guided by airplane or captive-balloon observers. In other words, the pill-box arrangement was merely a so-called "zone of defense" in which enemy observers could not direct artillery hits with any degree of accuracy because nothing was clearly indicated. The troops holding the positions in the defense zone were echelonned in depth of feeble density in front, but increasing progressively in strength toward the rear, where special shock regiments and regular infantry were held in force for sudden, smashing counter-attacks.

In resisting an offensive the scheme is supposed to have worked out as follows: The enemy—either British or French—expended in his customary lavish manner tens of thousands of shells in mussing up the ground in front of him, which in this case was the German zone of defense. By the law of proba-



© International Film Service.

Digging Trenches by Machinery Instead of by Hand

Digging trenches by hand is hard work. It takes a long time. And in a war where thousands of miles of trenches were required, it was to be expected that mechanical means would be employed sooner or later. During the war the armies devised special ditching machines, such as these French ditchers, for digging communication trenches.

bilities only a small percentage of German shell-hole positions, pill-boxes, tree shelters, and so on were put out of action. As the enemy laid his moving curtain of fire or barrage to protect his advancing infantry waves, the German defenders still clung to their shelter; but at the moment the barrage passed over they took up their positions and opened fire with hundreds of machine guns on the enemy infantry. When these had been considerably cut down and weakened, the German forces scattered about and reinforced by selected shock corps and regular infantry in the rear came up and, turning from the defensive to the offensive, attempted to oust the enemy troops.

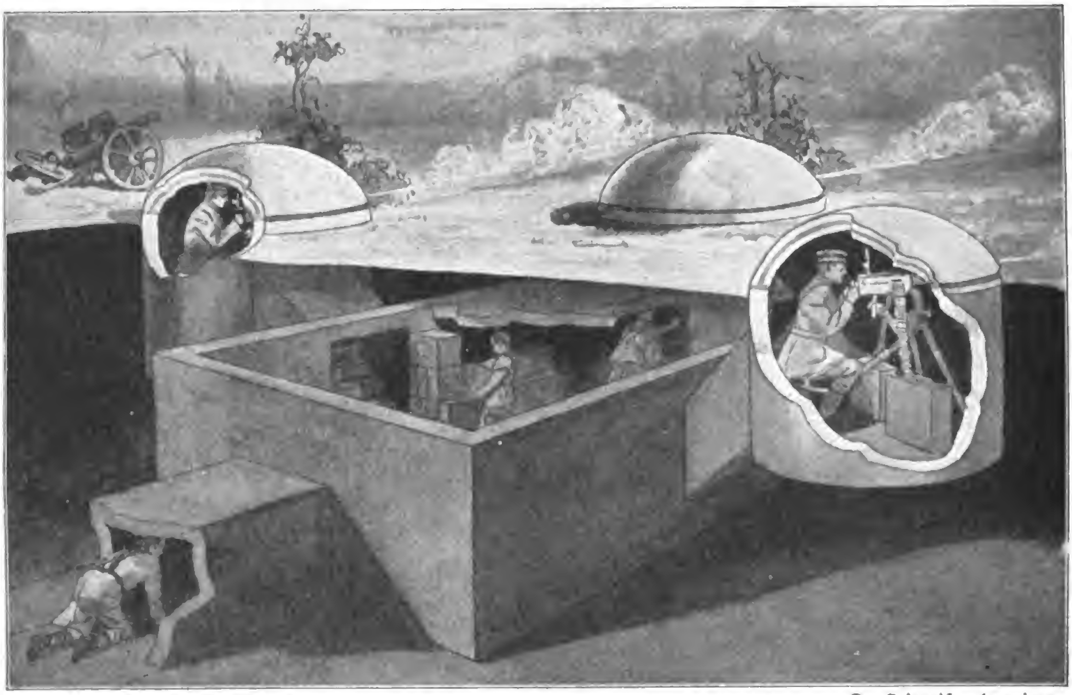
The success of this scheme, according to captured German orders, depended largely on camouflaging the machine-gun posts. Earth removed in preparing posts had to be thrown into unoccupied shell holes, or if the configuration of the terrain permitted, had to be scattered on the surface. In this manner dugouts could escape aerial observation. The comfort of the scattered garrisons evidently interested the German High Command but

French Official Pictorial Press, N. Y.

German Shelters in the First Line Trenches at Pleimont

little. They were told that if the humidity of the ground prevented the use of mine galleries, it would be sufficient to have simple shelters against shrapnel. Immediately behind the first-line shell-hole centers of resistance for machine guns, dugouts should be available for shock troops and such reserves as were sent forward, if possible; but failing in this they were to be assembled and held in readiness in the open.

Villages were to be avoided by infantry, and concentrations were to be made in sheltered spots in the open, such as in shell holes, behind hills, in hollows, and in woods, the main point being to avoid detection by enemy airmen. The German High Command had learned by experience that villages drew enemy fire.



During 1917 the Germans Made Extensive Use of Concrete Forts Known as "Pill Boxes"

These "pill boxes" ranged from small round shelters large enough for one or two men and a machine gun, to a blockhouse of considerable size, accommodating several gunners and helpers. This one, for instance, has three turrets, with a machine gunner in each. Underground are kept the stores of ammunition. The approach to the turrets is through the underground chamber, as shown.

Barbed wire still played a prominent part in this new German defensive scheme. Not only was a more or less continuous line used in front of the first-line shell holes, but it was used throughout the defensive zone for directing the attacking troops into the most favorable positions for the German machine-gun fire. Furthermore, each pill-box and shell-hole position was to be protected by a belt of barbed wire.

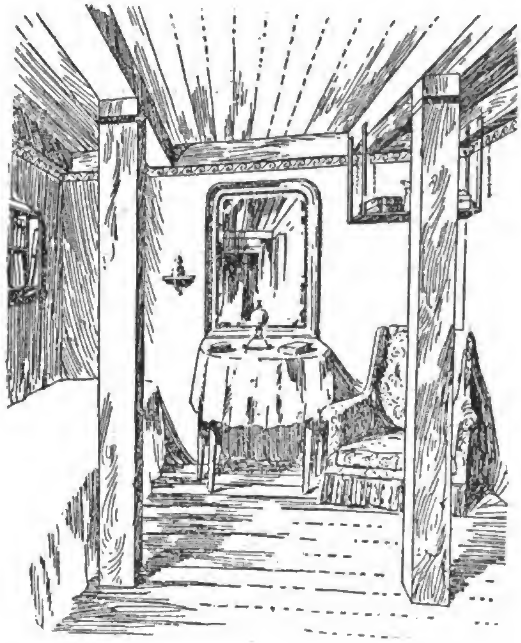
DESPITE ALL THE ATTACKER STILL HAS THE BEST OF IT

How these German plans worked out we all know from the British offensives of 1917. The very thing that the pill-box was intended to foil, tremendous gun fire, proved its undoing. For the British and French merely doubled, tripled, and even quadrupled their gun-fire, thus increasing the probability of hitting each and every pill-box and machine-gun shell-hole position. And then the barrage fire was not only shifted ahead in regular

steps, but was swept from side to side as well. Most important of all, however, the Allies planned each offensive beforehand, rehearsed every detail, and the attacking troops were assigned definite objectives which were well within the range of the supporting artillery. The last-mentioned fact answered the question then so often asked: Why do the Allies only advance a mile or two at a time?

During the British offensives of 1917 the barrage fire consisted of three distinct walls of shells and bullets: the heavy artillery working at long range; the field artillery working at short range, and the machine guns laying a curtain of bullets at a still shorter range. It was reported at the time that the last-named barrage proved very effective in practice; for when the British infantry got beyond the range of their artillery, as they did in some cases, the machine-gun barrage served to break up counter-attacks by the Germans.

If the development of artillery barrages has been a most difficult undertaking, the machine-gun barrage has been all of that and more. We are told that much patient practice has been necessary to adapt the machine gun to this work. It is more difficult to control the flat trajectory of the machine gun than that of the high-trajectory artillery piece. Therefore, many experiments had to be performed until it was decided how closely a bullet barrage might be safely applied. With the machine-gun barrage perfected, the gunners following close on the heels of the advancing British infantry were able to maintain a hail



Courtesy of Scientific American.

German Officer's Bedroom

Showing that the Teuton cave-man had all the comforts of home.

of bullets before the attackers, so that Germans essaying a counter-attack were doomed to certain failure at the very start.

THE WAR OF THE TRENCHES

Why It Required Four Years of Constant Study and Ceaseless Effort Before the Intrenched Lines on the Western Front Were Successfully Broken and Overrun

By Austin C. Lescarboura

FOR the man interested only in broad general principles, the course of 52 months' fighting on the Western front, where the war was won and lost, is briefly told. The Germans tried to win the war in a single rush. Failing here, they dug in and tried for a deadlock. For two and a half years the Allies sought means to break this; then the entry of the United States made it necessary for Germany to seek a positive rather than a negative victory, and the Kaiser's troops took over the effort to drive the war into the open. They failed again, but in the failing gave the Allies an opportunity to put accumulated ex-

perience to such good effect that the war indeed was forced into the open, in a fierce continuous four-months' fight. And then the Germans threw up the sponge.

For a full account of all this, of course, we must look to another volume. But it is in order here to pause for a moment and make a brief survey of the rôles played, in the forcing of the war into and out of the trenches, by the various weapons which we have described; and of the manner in which these and other means of fighting were applied.

© International Press Exchange.

German Skittle Alley in a Trench

BARBED WIRE AND THE MACHINE GUN

It was after their great defeat on the Marne in 1914 that the Germans fell back some distance and established themselves in trenches, quarries, rocky caves, and along ridges and hills. When the Allied Armies caught up with them they found the Germans solidly established, and the first attempts to push the invaders back were met with heavy machine-gun fire.

At that time the French and British had little in the way of heavy artillery; the French 75-millimeter (3-inch) and the British 18-pounder (also 3-inch) field guns which had served admirably in the open warfare of the early battles, were found of little avail against the strongly intrenched Germans. Besides, the Allies had used up most of their ammunition, as was likewise the case with the Germans. Indeed, it has been pointed out by a well-known authority that if the Allies had possessed sufficient ammunition of the high explosive variety, let alone a sufficient number of heavy guns or artillery of the mortar design, they could have blasted the Germans out of their improvised trenches and rushed them back to their own borders, thus bringing the war to a speedy close.

Infantry attacks were soon crushed by the murderous machine-gun fire from almost countless German weapons. In fact, the Germans, with their usual foresight in military matters, must have had much in excess of 50,000 machine guns at the outbreak of the

Courtesy of Scientific American.

Cracked Like Egg Shells, Although Built of Concrete and Steel

The Germans sprung a surprise on the world by their powerful mobile howitzers, which smashed the Belgian fortresses in short order. Steel cupolas and concrete defenses, of the type depicted, were soon reduced by German high-angle shell fire, to chaotic masses of twisted and broken steel and loose masonry.

war, as against a few thousands among the French, British, and Belgians. While the other nations had looked upon this weapon as an emergency one, only to be employed under certain favorable conditions, the Germans alone estimated the value of this quick-firer to be equal to 200 riflemen or more, when installed in a trench or other sheltered position, and surrounded by barbed wire or other obstacles; indeed, there are numerous instances where a single weapon has held up a regiment and even a brigade. A machine gun and its crew makes a small and difficult target for hostile artillery fire, as compared with 200 men; and therein lies the secret of its success. It is the rattlesnake of modern fighting, so to speak, and is a far more dangerous menace than the huge 16-inch cannon with its one-ton projectile. It is more dangerous because it lies in wait under cover, and strikes with its leaden venom when the victims least expect it.

As an auxiliary to the machine gun the barbed-wire belt is second to none. The Germans in due course erected wide belts of barbed wire in front of their trenches, so that all attempts to rush their trenches were checked by these sinister strands while riflemen and machine gunners blazed away. Before the attackers reached the trenches they had to make a way through a jungle of barbed wire in the face of a hail of hostile bullets. And since they also had to live, by the winter of 1914-15 the British and French were also established in a continuous line of trenches facing the Germans. At some points the space between the hostile lines, the so-called No Man's Land, was but 10 yards in width, while in others it was several miles, depending upon the topographical conditions and the military activity.

So it was that the Western front became stationary. War had become a motionless, colorless and undramatic business of man-killing.

THE RÔLE OF THE ARTILLERY

In the early days of trench warfare the artillery was mostly of small caliber on the Allied side, and was placed a short distance behind the trenches. The Germans, being more fortunate in the matter of big guns, disposed their small pieces near the trenches and their big units farther back.

Artillery was mostly employed to interfere with the enemy infantry in the trenches, making their life as miserable as possible and harassing the work of organizing old or new positions. When hostile guns became too boisterous and bothersome, artillery was directed against them in what is known as counter-battery work. So both sides soon made it a practice of searching out and shelling each other's guns. It became necessary to hide the guns to protect them from hostile fire; and in that requirement was born the new art of camouflage, or military deception. Used only on artillery at first, camouflage was eventually extended to everything at the front.

The first infantry attacks on enemy trenches were too costly in proportion to the gains. The barbed-wire belts were cut by hand or shattered with bombs, by volunteers who knowingly and unflinchingly went forth to their death. The infantry which followed was subjected to heavy rifles and machine-gun fire before coming to grips with the enemy in his trenches. It soon became obvious that plain infantry attacks were entirely too exhaustive of man-power, and artillery preparation would have to be resorted to.

In September, 1915, the French launched a big attack in Champagne after an artillery bombardment of several days, in which hundreds of 75's (3-inch) and 155's (6-inch) guns were used. Barbed-wire belts and German trenches were obliterated, and the infantry advanced over the upheaved terrain in the face of machine-gun and rifle fire from such defenders as had survived the bombardment. The object of the attack was to breach the German lines and thus recover a large part of invaded France. But the German trenches were arranged one behind the other in great depth, and although the French captured the forward trench lines, the attack was brought to a halt in front of others farther back. The Germans had brought up reserves, having been warned of the impending offensive by the prolonged bombardment. And while the attackers made good progress over the terrain which had come under their artillery fire, they were finally brought to a complete stop by the heavy machine-gun and

rifle fire in the areas beyond the range of their guns.

The attackers, out beyond the support of their artillery, had barely sufficient time to intrench themselves when the opposing artillery opened fire and the enemy infantry attacked. Fighting at a great disadvantage, and with a limited supply of ammunition and few if any machine guns, the erstwhile attackers were often obliged to fall back or run the risk of capture or annihilation. And it so came about that the Germans often retook much of their lost ground in the course of such counter-attacks during the battles of 1915. On the other hand, when the Germans launched an offensive they advanced in dense waves, and after coming to a halt they intrenched as best as they could, amply provided with machine guns which they had carried up with them. Thus their strength in rifles and machine guns was such that Allied counter-attacks were not often successful. Still, the Germans paid a heavy price in advancing in their dense waves.

Life was held in cheap esteem in all such attacks. Ground was captured only to be lost, and then recaptured. Certain bits of trenches changed hands many times. Better methods of attack had to be developed. The Germans won position after position through sheer weight of numbers, and the Allied riflemen and machine gunners collected heavy toll in the dense masses of gray-clad troops. The world marveled at the discipline of those Germans who came on and on, often stumbling over walls of their own dead.

So it was at Verdun early in 1916. The Germans, realizing the vital importance of artillery, used hundreds of guns on a few miles of front. The torrent of high explosive and steel from concentrated batteries wrecked the forward trenches of the French defenders and buried and killed most of the occupants. Nothing could live through such frightful fire. And then the Germans came up in their usual dense formations, sweeping over all obstacles and resistance. For the first few weeks it seemed as if nothing could

British Tank *Britannia* at Camp Upton

This tank was brought to the United States during the war for the purposes of recruiting British and Canadian citizens in this country.

prevent them from taking the French fortress. Two of the important forts, Douaumont and Vaux, were captured. The Germans pressed on, irrespective of their steadily rising losses.

British Tank *Britannia* at Camp Upton

The *Britannia,* which was known in the war as a female tank, weighed 36 tons, and traveled over rough country hills and trenches at the rate of four miles an hour. She was armed with six Lewis machine guns.

BARRAGE FIRE AT VERDUN

The miracle of Verdun is now a matter of history. The French soldiers, sorely pressed as they were, doggedly held on. They succeeded in separating the German hordes from their artillery after each fresh onslaught, and in this manner brought the fighting conditions to more equal terms. Also, the French artillery introduced the barrage fire during the defense of the fortress. By means of the artillery barrage, or the concentrated fire of a large number of guns so aimed as to form a line or curtain of bursting shell, the French were enabled to bar the path of the attackers. Later this barrage was perfected to a point where it could be progressively shifted, forward or backward, forming the creeping barrage. And then at last, after almost two years of war, the big guns of the British and French were at last turned out and ready for battle.

The collective battle of the Somme was a conflict of artillery. The British and French literally blasted their way forward by yards at a time. Before a single infantryman went "over the top," the German barbed wire and

© Underwood and Underwood.

German Invention for Use Against Tanks

This tank rifle was captured by the Canadians. It fired a cartridge about five inches long, and had a bore of one-half inch.

trench works were utterly destroyed—wiped from the face of the earth by concentrated explosive and steel splinters. The Germans sought protection in deep underground chambers or dugouts, only to be buried alive by the explosions of the huge shells. Some day it may be possible to estimate the number of Germans buried alive on the Somme battlefield, and no doubt the findings will be appalling.

In order still more to protect the infantrymen, the Allies made use of the creeping barrage, moving some 100 yards in front of their men. The idea of the creeping barrage or moving wall of bursting shell was to keep the German defenders below the surface, in their dugouts, and out of the trenches from which they could direct machine-gun and rifle fire at the advancing troops. If they could be kept below the surface, the Allied attackers were protected until they reached the German positions and were at the entrance to the dugouts, with hand grenades ready to fling down if the occupants refused to come out as docile prisoners. But all the while the protracted British and French bombardments gave the Germans ample warning of an impending offensive, so that they could bring up their reserves.

© Underwood and Underwood.

Canadians Digging In While Whippet Rolls By

This squad is digging trenches and waiting for the next wave to pass through them. A whippet tank is seen returning after an attack on enemy machine-gun nests.

WANTED: A CANNON TO ACCOMPANY THE INFANTRY

So the great difficulty in all the Somme engagements was to keep going at a reasonable cost in blood. The German front lines were pierced and the infantry advanced; but after a gain of a mile or two the attack was drowned in blood, so to speak. Allied artillery could not be moved over the battlefield, which was upheaved and devoid of railroads or highways. Indeed, it was usually as if a sea of mud had suddenly become frozen. Days were required to build roads and bring up the artillery and shell over the desolate terrain. The task of reorganizing the supply service was magnitudinous; and meanwhile the Germans were offered a few days or weeks to recuperate.

Some sort of artillery which could keep pace with the infantry was the solution of the trench attack, it seemed. The French gave this matter much thought and in time introduced several weapons, among which one was

finally adopted, namely, the 37-millimeter (1½-inch) quick firer. This cannon, which weighs 240 pounds, fires its shell some 2,500 yards. It can be mounted on a folding tripod or on a small gun carriage.

The British introduced the Stokes mortar, or high-angle fire piece, weighing about 100 pounds for the smaller model. This mortar fires a six-pound shell, while a large model, weighing about twice as much, fires a shell weighing over 15 pounds.

The idea of "accompanying cannon," as the French called them, was excellent in theory; but when tried out in battle there rose at least one difficulty, the matter of shell supply. While the French and British small guns could keep up with the advancing infantry, it was found next to impossible to maintain the necessary shell supply out in the open. With a rate of fire of from 8 to 10 rounds per minute, the French cannon or the Stokes mortar consumes numerous projectiles in a short space of time. The only means of bringing up shell is by the men themselves, although toward the end dogs were employed as ammunition carriers. One man can carry five shells on the average, so that for 100 rounds, or about ten minutes' bombardment, upwards of 20 men would be required as ammunition porters.

Because of the impossibility of maintaining shell supply, the artillery of accompaniment did not prove the solution of the trench-attack problem, although in numerous instances such artillery has proved invaluable in the reduction of strong machine-gun nests.

ARTILLERY THAT CRAWLS TO THE ATTACK

Then, on a September's day in 1916, the British launched the greatest mechanical surprise of the war—the tank. The Germans were taken completely by surprise, and even in the seriousness of battle the soldiers of Great Britain had time to laugh over the exploits of the first landships as they traversed the upheaved terrain of the Somme. For days newspaper correspondents sent back glowing accounts of the work of these new steel monsters. So the work of the tanks is by no means unknown; suffice it to say that here at last was a solution of the "artillery of accompaniment." For the tank not only carried one or more guns, but it had motive power sufficient to take it over the shell-torn and pitted battlefield; it carried ample sup-

Special Tractors for the Transportation of Renault Tanks

plies of shells; it carried the necessary crews; and, lastly, it was a veritable steel blockhouse, offering protection to its crew.

The first tanks proved the terror of the German infantrymen; for once their machine guns were useless. Those German gunners who remained at their machine guns were either shot or crushed to death by the tanks, which traveled astride the trenches. Houses, which had heretofore afforded shelter to machine gunners, were bowled over or battered to pieces by the powerful tanks.

© Underwood and Underwood.

A British Land Ship Afloat on American Soil

Americans first became familiar with tanks and what they could do through the generosity of the British, who sent the *Britannia* to this country for a tour. This land ship, which is here shown, amazed Americans by crushing barbed-wire entanglements, crashing through brick walls, climbing over fallen trees, etc.

By the beginning of 1917 the Germans, appreciating the offensive value of the tank, even if they had indulged in much ridicule at first, prepared to combat the new form of attack. Pits, lightly covered over so as to hide them; special guns, in many cases worn-out field guns whose accuracy was sufficient for firing point blank at tanks but a few hundred yards away; buried mines, designed to wreck the tanks; and other schemes were introduced as part of the German defenses. Later the Germans were provided with special anti-tank rifles, firing a bullet about three times the size of the conventional rifle bullet, and capable of penetrating the steel plate of the tanks. But all these precautions were only moderately successful, and then only if they were available at the point of the tank attack. The tank, indeed, was one of the potent reasons that led the Germans to install the pill-box system of defense.

November of 1917 will always be looked back upon as the month of the great lesson in trench tactics. For it was during that month that General Julian Byng, commanding the Third British Army, introduced a new and revolutionizing means of attack on the Western front.

On a long front facing the city of Cambrai, which was then in German hands, General Byng opened up an offensive with hundreds of tanks instead of the usual artillery preparation. In the early hours of the morning his tanks went forward and through the barbed wire—tearing great gaps through which poured the British infantry. In a few minutes the tanks and infantry were over the German first line and beyond the second

and even beyond the third, the utterly surprised Germans having had no time to put up a satisfactory defense. No German reserves were at hand, and General Byng's men and tanks pushed up to the suburbs of Cambrai. Had he possessed the necessary reserves at that moment, he could have exploited the breach in the German line and scored an important victory. As it was the Germans came back with a heavy counter-attack several days later, regaining much of the lost ground. Still, General Byng's experiment had been successful—and indeed a revelation to both sides.

VON HUTIER'S SCHEME TO WIN THE WAR

The importance of surprise as obtained by General Byng's attack at Cambrai made a profound impression on German military leaders. So much so, in fact, that they set to work devising some means of surprise attacks which would enable them to breach the Allied line and then exploit the breach to the utmost.

The honor of working out such a scheme fell to von Hutier, who had had much practical experience in his own brand of tactics against the Russians on the Eastern front. In fact, a surprise attack of his own conception had enabled him to capture Riga.

Von Hutier's plan of attack was extremely simple in its main essentials. In the first place it depended on the weight of numbers. The attackers were to have a superiority of numbers of anywhere from two to five. The attack was to be delivered as a complete surprise. Losses during the attack were to be disregarded, no matter how appalling they might prove. Everything was to be done to push the attack to a decision, leaving the counting of the costs to a later date.

In order to gain complete surprise in these days of elaborate intelligence services and airplanes, the Germans had to exercise the utmost precautions. To this end the troops were brought to within 20 or 30 miles of the point of attack, and quartered in villages and woods and ravines and other forms of cover so as to be hidden from the prying eyes of Allied birdmen. When troops had to be moved, they were moved at night, without music, singing or other noise. Fires, smoking and lamps of all kinds were not to be tolerated while on the march. In fact, so as better to conceal the movements of so many troops, much marching was undertaken over rough fields, in order not to leave telltale marks on the roads. It is even said that some roads were camouflaged with covers painted to represent the roads below, so that heavy traffic could be handled in daylight while Allied observers saw only what appeared to be empty roads.

Guns for the attack were brought up at night and installed with the greatest precaution to prevent their presence becoming known by the enemy. In most instances each gun crew was only allowed three shells for ranging purposes, so that the enemy intelligence service, not noting any increased number of shells "arriving" on their side, would not detect the reënforced batteries.

Finally, realizing the value of the cannon of accompaniment, the Germans prepared a large number of *minenwerfer*, or trench mortars, for the attack. These mortars were mounted on carts to be drawn by horses or men. Field guns and light machine guns also were to accompany the infantry waves. As many as 68 batteries of four guns each are known to have been attached to two regiments.

Long artillery preparation, such as had marked the battles of 1916 and 1917, was abandoned in favor of a short but intense bombardment with poisonous gas shells with the idea of disabling the personnel rather than the defenses of the opposing side. The enemy front-line trenches only were to be more or less battered by a short but intense bombardment with thousands of trench mortars. Meanwhile the terrain in front of the enemy lines and beyond his first-line trenches was to be practically untouched, permitting of rapid movement not only of the troops, but of the artillery and supplies as well.

The Russian *débâcle* and the ignoble peace of Brest-Litovsk had provided Germany with numerous fresh troops from the Eastern front. In truth, thousands of guns were also obtained for the big offensive in the same manner, Russian guns among them.

A rigid course in training was given to the various units chosen to lead the big offensive. Already Germany had put into execution a

two-standard system in the German Army, whereby troops were designated as "shock troops" or "holding troops." The former were the élite troops, enjoying special insignia on their uniforms, first claim on booty and plunder, extra leaves of absence, and unstinted praise and decorations. The holding troops were merely to fill in or to bulk up the Army, as it were. They could be employed for holding quiet sectors; but when it came to offensives the shock troops led and the holding troops followed. That this system proved fatal in the subsequent defensive operations of the Germans is quite another question; as far as offensive operations are concerned, it appears to have been successful.

On March 21, 1918, the greatest blow in all history was struck by the Germans. It was the von Hutier style of offensive, and the real German bid for a made-in-Germany victory. The blow fell on the Fifth British Army, and never has a body of soldiers been called to withstand such an avalanche of armed men.

At least four waves of dense German infantry went forward in regular intervals, following the intense gas-shell bombardment and the trench mortar bombardment of the British first lines. The first wave was supported by the second, and the second by a third, and so on. Each succeeding wave supported the preceding one, filling up gaps and taking advantage of such breaches as were caused in the enemy lines. German troops piled up at stubborn points of resistance and rapidly reduced them. And still reserves came up by automobile truck or railroad. Meanwhile a German barrage fire played on the British back areas with a view to cutting off reënforcements.

© *Kadel and Herbert.*

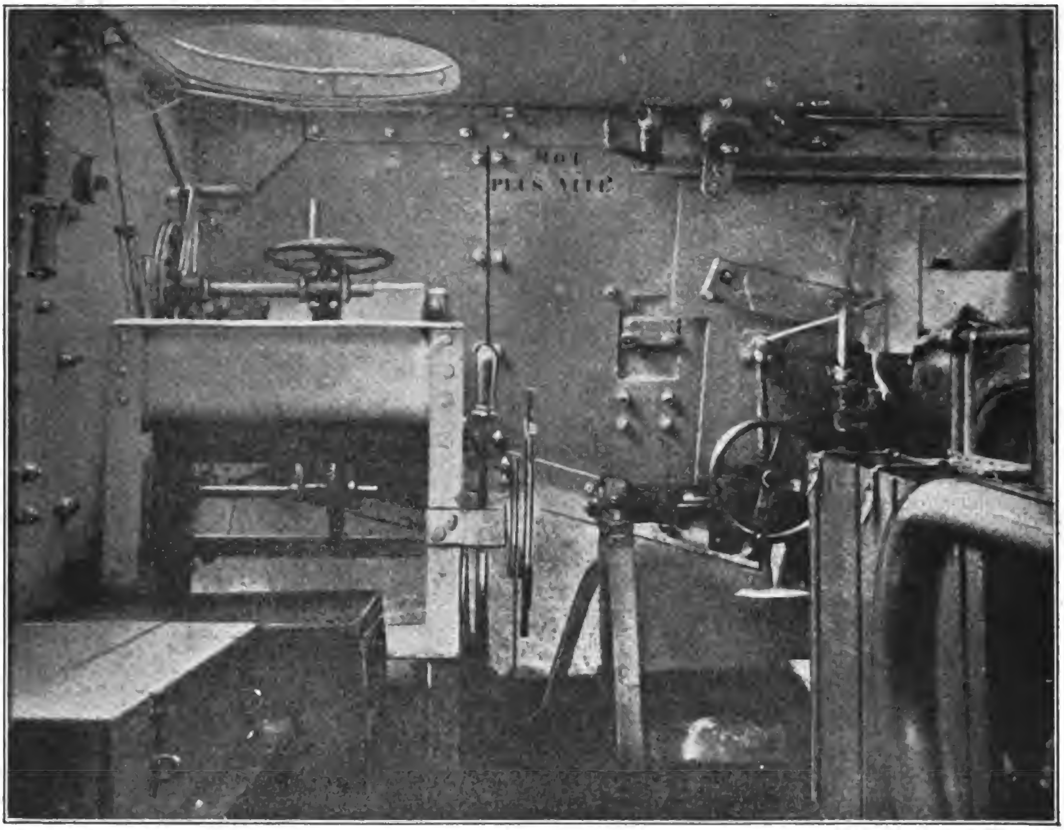
French Tank Operator at Work

The tank provides a small space with everything right under the operator's hand.

It appears that each German division in the attack had two regiments in the front line with one just behind in support. Each regiment, in turn, had its three battalions one behind the other. Each battalion was heavily supplied with machine guns mounted on wheels. Between the first two regiments and the third there was sandwiched a vast array of mobile artillery, particularly *minenwerfers* of the type already mentioned. Behind the third regiment came such tanks as the Germans had available, and the supporting artil-

lery for firing gas shell and laying barrages.

The organization was complete, in typical Teuton style, to the last cart wheel. The infantry units were provided with sectional bridge members to bridge over barbed-wire entanglements and destroyed trenches. Engineer units were provided with iron sheets to lay over rough ground so as to form smooth and hard roads for the heavy supply traffic. whelming numbers. The Germans gained a wide strip of territory and many Allied prisoners remained in their hands; but the war was not ended. The Germans shifted their attack north, and again scored important gains at first, only to be brought to a halt. By the following June they attacked in much the same way the French positions along the Chemin des Dames, and succeeded in over-



© Kadel and Herbert.

Interior of a French Tank

Members of the various tank corps have testified that tank-sickness is far worse than seasickness.

This was to be a classic offensive, with no halt called until Calais, Dunkirk, Amiens, Arras and Paris were captured, and the Allies were ready to sign on the dotted line of the peace articles prepared by Germany.

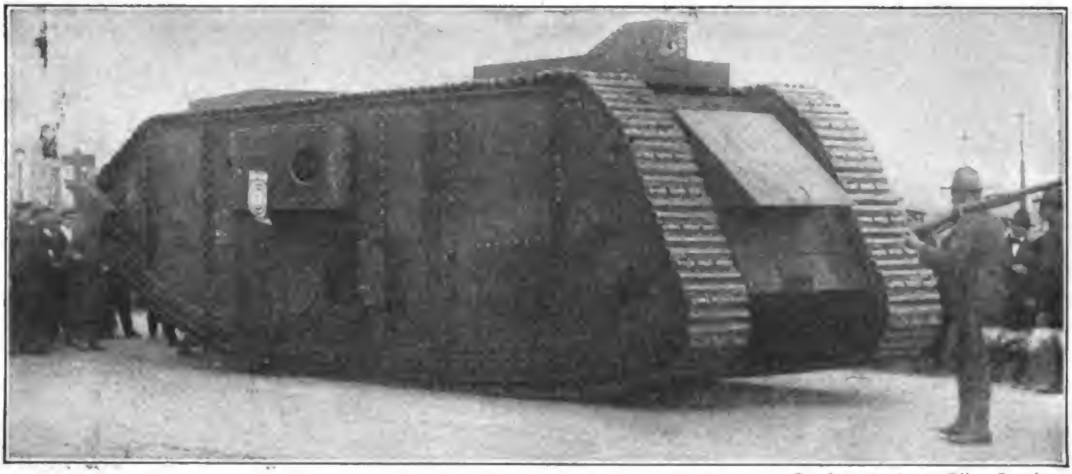
The story of the great attack of March 21st is now written in history. The world knows of the plucky and glorious defense of the British Fifth Army, which fell back slowly, with its face toward the enemy, contesting every foot of ground despite over-running a large stretch of territory leading to the Marne River, where they were finally brought to a halt. By now it seemed as if nothing could withstand the first shock of von Hutier's tactics, and serious fears were entertained for Rheims, Epernay, Châlons, and even Paris, when the next German blow (July 15th) fell on the Champagne front.

And on a large part of the Western front the armies were at last in the open: trenches had ceased to exist.

HOW VON HUTIER'S TACTICS WERE DEFEATED

The great "peace offensive," which was to end the war as far as the Germans were concerned, was announced a long time in advance by the Germans, very much after the fashion of a press agent announcing the coming of a circus. This final offensive was to give them Rheims, Châlons, and Epernay, splitting the French line in two, and opening the roads to Paris. The fronts to be attacked were those along the Marne and about Château-Thierry, since made famous by our American troops, and the Champagne front east of Rheims, held by General Gouraud.

Up till the eve of the German attack in Champagne, every German offensive of 1918 had gained considerable ground and prisoners. The von Hutier tactics were irresistible at the outset; and there was considerable apprehension on the part of the Entente authorities with regard to Paris, for the margin between the front lines and the French capital did not permit much more retirement. In fact, every foot brought the German infantry that much nearer to Paris; more important still, every foot brought more and more German cannon within range of the metropolis. Could the offensive be held?



© *International Film Service.*

The Largest Tank in the World

This American tank weighs 45 tons, and is run by steam.

All the foregoing, which is really in the realm of strategy, is necessary for a better understanding of the tactics which turned the tide of the World War. It is also necessary to add the strategical information that the German armies south of the Vesle River were supplied by a single railroad which passed close to the existing French front. If that supply artery could be severed before the Germans captured Rheims and the high ground back of the famous city, thereby obtaining new supply lines, the German armies in the Marne pocket would be in a bad way and in danger of capture. Thus it was a matter of defending the Rheims and Champagne fronts while the Allies found ways and means of cutting the German artery.

On receiving definite information of the coming German attack, General Gouraud withdrew his troops from the first-line trenches, leaving only a scattering of machine-gun nests and small centers of resistance at advantageous points. The men garrisoning these little forts were picked men, who volunteered for this service, which meant bitter fighting, with death or capture as the inevitable sequel. In other words, General Gouraud immediately organized a defense in depth—an improvement over the German system of defense employed in 1917.

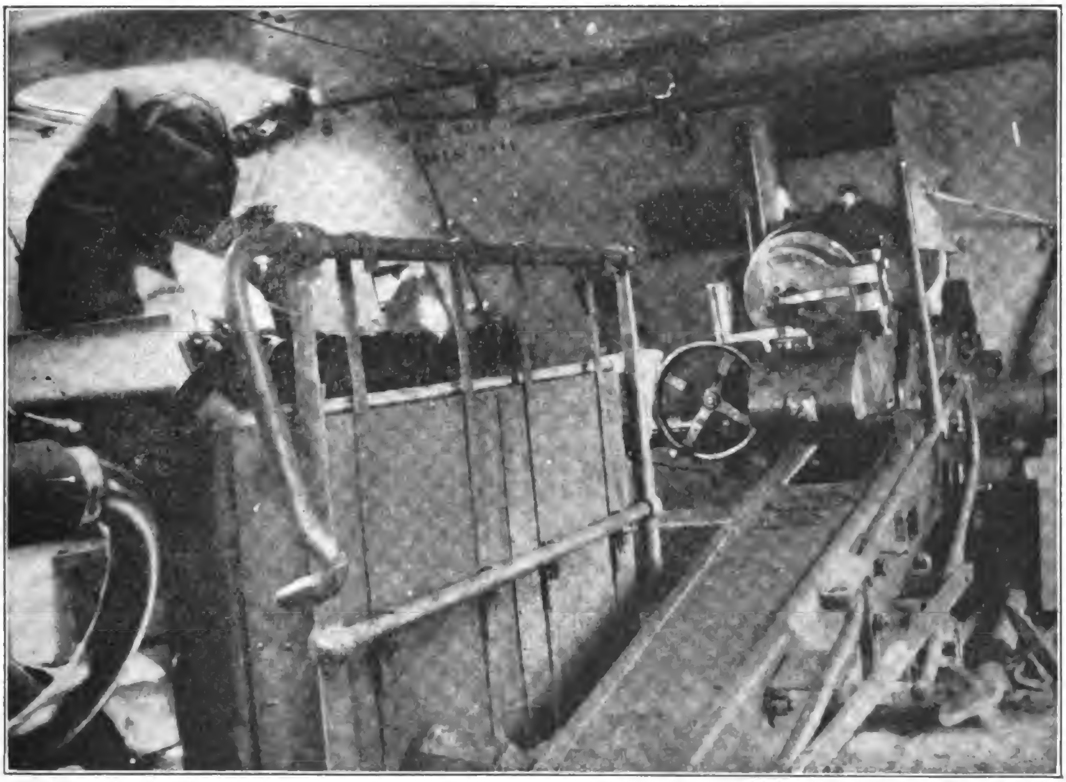
When the German artillery broke out in full volume on the erstwhile first-line trenches of the French, thousands of shells were poured out on those empty trenches, followed by more thousands. Meanwhile the French

artillery, knowing the time-table of the enemy, had been advanced up close to the German trenches, so as to open a hot fire on those trenches at a time when it was known that the Germans were assembling for the attack. How many Germans were slaughtered in those trenches may never be known; but the number must have been appalling. Still, the German has a one-track mind. He follows his program from the overture to the finale, with never a deviation even if such a procedure would prove his very salvation.

At the precise minute set for the infantry attack, the Germans "went over the top." Meanwhile the French artillery had been registered on the open ground in front of the French first-line trenches, and the Germans were again mercilessly slaughtered as they advanced in close order toward the empty trenches. Again the artillery fire was shortened, this time on to the empty French trenches, which were rapidly filled with such Germans as had come through the barrages. Greatly weakened, the Germans came on toward the real French trenches, some two miles farther, only to be met with a hot artillery and machine-gun fire.

All the while the isolated groups of Frenchmen, by means of wireless and carrier pigeons, had kept the French command informed as to the progress of the German masses on all sides of them. One by one these little groups of Frenchmen were wiped out by the overwhelming masses of Germans, but not before the defenders had given invaluable information to the French commanders and artillery. These isolated posts also accounted for large numbers of Germans, by means of their enfilading machine-gun fire.

By noon of the 15th the Germans had launched seven distinct infantry attacks, and had failed to gain ground other than that abandoned by the French in order to create the defense in depth. The German offensive



© International Film Service.

Inside a French Tank in Action

The picture shows the driver and the "75" rapid firing gun.

had proved a complete fiasco. An antidote had been found for von Hutier's awe-inspiring tactics.

THE BATTLE THAT TURNED THE TIDE

In conjunction with the Champagne attack the Germans had also attacked along the Marne River, to the left of Rheims. Here they gained some ground until their line took the shape of a deep pocket. At the left of this pocket, as viewed from the Allied side, was the army of one of the greatest offensive leaders of the French Army—General Mangin. Realizing that if the Germans were given sufficient rope they would hang themselves, General Mangin had suggested a plan to Generalissimo Foch which was immediately approved of.

A surprise party was prepared for the Germans in the Marne pocket. They thought they were marching on to Paris. Surely Foch's reserves had been exhausted by the great offensives of 1918, and the Germans had nothing more to fear! But this was still another time that the German high command had underestimated the foe's strength.

In the fastness of the Villers-Cotterets Forest to the Germans' right, there was great activity during the three days prior to July 18th—such activity as perforce must accompany the assembling of a modern army of attack. Thousands of guns and hundreds of new, two-man tanks, similar to the "Whippet" tanks, also two-man tanks, of the British, were brought up. Fortunately, a thunderstorm raged while the clanking, chugging tanks were being brought up to within a few hundred yards of the German outposts, so that their presence was not betrayed.

On the morning of the 18th General Mangin ordered a short bombardment of great intensity, merely to remove such obstructions as the Germans had hurriedly thrown up on their right flank. Then the Allied troops swept forward, in company with hundreds of tanks. The tank crews had been trained for months in the new tank tactics, whereby infantry and tanks coöperated in perfect liaison. Neither one got ahead of the other, and the Germans faced a solid unit of tanks and infantry. The tanks, making ten or twelve miles instead of the three to five miles of the earlier tanks, were able to maneuver rapidly, reducing all machine-gun nests in short order. The tanks did much to reduce the German obstacles and machine guns; and as in the attack of General Byng during the preceding November, here indeed was a surprise attack.

Of course, the tanks were not the only means of scoring a complete victory. The Allied troops used plenty of gas shell, portable machine guns, flame throwers, and all the other infernal weapons of warfare as expounded by the Boche.

History has already recorded the results of General Mangin's counterblow and the successive closing in of the other armies on the Marne salient. The Germans lost over 1,200 cannon, thousands of machine guns, large stocks of munitions and supplies, and well over a hundred thousand prisoners. And all because they were attacked unexpectedly, and because their single supply line was cut before their overwhelming numbers nearby could be brought back to face the new thrust. The gigantic German machine was simply wrecked by an unexpected jar.

The British also had a surprise party for the Germans. On August 8th Marshal Haig's legions swept forward after a "crash" bombardment from thousands of guns, and in company with hundreds of tanks of the "Whippet" type. These light tanks, like the small French Renault tanks, are able to maneuver rapidly over any kind of terrain, and, what is more, they can more than keep up with fleeing bodies of Germans, as contrasted with the cumbersome, slow-moving tanks of 1917.

Striking first at one part of the line, and then at another, and still at a third, and so on, Generalissimo Foch, by means of his vast fleets of tanks and his constantly mounting reserves, was able to "keep the Germans guessing." The Germans had not had the customary artillery notice of an attack, and hence were not able to bring up reserves to meet it. And with the gradual weakening of their numbers, the Germans were no longer able to shift troops, even when informed of a coming attack.

Taking a leaf from the book of General Gouraud's defense in Champagne, the Ger-

A British Tank in Action

During the campaigns of the latter half of 1918, when the full possibilities of coöperation between the land-ships and the infantry were being realized. The tank preceded and covered the advance of the foot soldiers.

mans at first attempted to halt the powerful Allied attacks by a copied method. They attempted to organize defenses in depth whenever threatened with an attack. As a result the Germans gave up much ground in France and Belgium under the pretense of forming outpost zones for their defense in depth. It is on record that some German commanders gave up hundreds of miles of terrain on such flimsy excuses, until finally the German High Command, alarmed at the rapidity with which the retreat was approaching the German frontier, called a halt to the forming of outpost zones.

It is one thing to form a bona-fide outpost zone and quite another to form an outpost zone every day, so that to-day's front-line trenches become to-morrow's outpost zone, and so on. A defense-in-depth system appeals to men who have to withstand powerful and overwhelming attacks; but rather than face such attacks the Germans gave up much ground toward the close of the war.

© Underwood and Underwood.

At the British Tank Gun School

The Prime Minister of Newfoundland inspecting a tank gun on the Western Front.

THE MACHINE GUN AND THE TANK

The tank served to take the Allied troops through the Hindenburg line. That great maze of concreted tunnels and trenches and countless machine-gun blockhouses, with belt after belt of barbed wire, was reduced only after desperate struggles. The British, aided by two American divisions, the 27th and the 30th, spent fourteen days of the most persistent and costly fighting to traverse some dozen miles of that formidable frontier barrier which the Germans had for years been building across France.

Once the troops reached the open country beyond, the war took on a new form. The tanks continued to protect the infantry during an advance, and to break up enemy bodies.

They served to attack intrenched foes. They continued to permit the Allies to deliver surprise attacks against powerful positions, although with the overwhelming numbers at the disposal of the Allies toward the closing days of the struggle, this element of surprise no longer had the former significance. Indeed, the last offensives were waged on a 250-mile front, so that there was little left of the Western battle line where a fresh attack could be launched in secrecy. The main function of the tank in the new open warfare was to support the infantry; to serve as the real accompanying or supporting artillery so long sought by the French military men.

The melting of the German Army was more or less sudden, yet the Germans fought well and desperately. They relied almost entirely on their thousands upon thousands of machine guns to halt the victorious Allies. In fact, it seemed at the time that the Germans had no end of these murderous little weapons, which, in the hands of skilled gunners, have effectively smothered the dashing warfare of bygone days. Every farmhouse, every tree, every hill, every rise in the ground, every hole—everything, to be sure, had a German machine gunner and his weapon. The Allied troops in the fateful days of October and November, 1918, had to force their way forward over the bodies of these desperate machine-gunners, who were instructed by their masters to collect such a toll of Allied lives as would cause the Allied powers and the United States to pause, appalled at the cost.

Fortunately the tanks proved to be the greatest destroyers of machine guns and their crews. It is estimated that a battalion of tanks—thirty-six—saved the lives of about a thousand men every day they were in action. Which means that the losses from German machines were materially reduced, and that the advances were made at a lower cost than would have been the case under former conditions. They were in fact a picnic, compared with what they would have been.

The Germans knew all this. They realized that the tanks were proving the undoing of their machine guns. They tried to combat the tanks, after their failure to produce equally good tanks. They made use of special anti-tank rifles firing a heavy, armor-piercing bullet of about three-quarter inch diameter. They dug pits, lightly covered over, as traps for the tanks. They placed obstacles of steel and concrete in the path of tank attacks. They even inundated large tracts of land to stop tank fleets, but all without avail.

For the whole question of tank attack resolved itself into a matter of surprise and numbers. The Allies did not employ the tanks where the Germans were prepared to receive them. Instead, they resorted to other methods of attack along more conventional lines, while sending their tanks by fast motor trucks to other parts of the line. And then there was the matter of numbers. A German anti-tank gunner could take care of two or three tanks; but when confronted with six or more he was unable to account for all of them. They were certain to close on him sooner or later, and he was either shot where he stood or crushed to death.

THE TANK IN TIME OF PEACE

With the coming of peace, the warring nations found themselves stranded with a vast quantity of war-making apparatus for which there was no immediate use; and of course the ingenuity of inventors and engineers was taxed to find employment for as much of this material as possible. In this search they were quite successful; and even for such a fundamentally warlike machine as the tank they did not despair of finding peaceful uses. Many of the smaller French tanks were put to work in the tourist-infested regions, affording a convenient means of transporting these people up mountains, and in fact threatening to make the old style of pedestrian mountain-climbing more or less obsolete. Others were set to work at heavy hauling and grading in the invaded districts. With a huge flat platform substituted for the armored top and sides, others were used in the transport of heavy materials, such as rails and machinery. Again, the French dismantled the armored portions of many tanks and used the caterpillar chassis as the base for an agricultural tractor. Altogether, there was quite a peace-time demand for these discharged minions of war.

TANKS OF ALL NATIONS

How the Idea of the Crawling Fort Was Gradually Evolved by the British and French and What Became of It

THIS is a story of a wonderful idea which was progressively worked out until it became the leading invention produced by the war. Indeed, while this division and that brigade of one army or another have been seeking all the credit for the winning of the Great War, the leading authorities and students of the struggle have at last set aside these immodest claims by stating in clear, unmistakable language that this great Allied invention—the tank—was the decisive factor in the final smashing of the skilfully entrenched Germans.

The tank idea originated at the very beginning of the war, back in those dark days of 1914, when the Germans swept over France and Belgium, met defeat at the Marne, and rolled back some distance only to intrench themselves behind continuous belts of barbed wire. Then the British and French tried to break through the barbed wire and the German trench system, and were only successful here and there on a small scale and at a tremendous cost in blood and treasure. The Germans realized the defensive value of barbed wire backed up by machine-gun and rifle fire. In fact, they halted millions of strong, well trained Russians who rolled on up to the barbed wire defenses in the east, only to be slaughtered by the tens of thousands. Obviously, weight of numbers counted for little in the face of such defenses.

THE MATTER OF GETTING THROUGH BARBED WIRE

Then the inventors set to work to find some way of getting at the German machine gunners behind their barbed-wire belts. While intense shell-fire served to cut up the barbed wire, it was a crude measure at best. Days of bombardment were necessary before a dense defense could be reduced, and by that time the enemy had ample opportunity to make such dispositions as he thought necessary to meet the impending attack. Obviously, some quicker and more efficient method was necessary—some method that would retain the vitally important element of surprise for an impending attack.

In November, 1914, a French inventor, J. L. Breton, forwarded a plan to the French Minister of War, covering an armored automobile engine driving a circular saw for cutting through barbed wires and their supports. The Commission for Inventions immediately appreciated the military possibilities of this idea, and encouraged the inventor to go ahead with a model. In January, 1915, experiments were carried on with the type of machine shown in one of the accompanying illustrations, consisting of a six-horse-power gasoline engine driving a circular saw held at the extremity of a pivoted arm which could be adjusted so as to bring the saw to bear at any angle or height. While the experimental machine was mounted on a simple factory truck, the actual military machine would have been mounted on an armored car driven by the same or a separate engine. But the inventor and military authorities soon came to the conclusion that the embryo tank would have to be more powerful, and in casting about for a suitable vehicle they came upon the familiar agricultural tractor, with continuous caterpillar belts.

At that time, however, it was impossible to secure an agricultural tractor, although M. Breton and Major Boissin, of the technical section of the French engineers, realized that an American tractor was the ideal mount. So it was finally with a Bajac tractor, placed at their disposal by the end of February, 1915, that the experimenters conducted their tests. Mounted at the rear of the Bajac tractor was a powerful set of shears, designed by M. Pre-

tot, as well as a horizontal circular saw intended to saw the wooden supports of the barbed wire a few inches above the ground. Obviously, the tractor was operated backwards in order to bring its cutting members into action. The shears worked fairly well, but the saw performed somewhat irregularly and was subsequently abandoned in favor of a moldboard arrangement. This contrivance gave excellent results when the tractor, which weighed about four tons, was weighed down with another ton to represent the weight of protective armor. After a very successful official test on July 22, 1915, the French Minister of War decided on the construction of six tanks of this kind. And it was the construction of these six tanks which caused the French Army to order the first 10 caterpillar tanks of the Schneider-Creusot type, on December 7, 1915.

Meanwhile other French inventors were at work, notably Messrs. Turmol, Frot, and Lafly, who followed out the idea of utilizing the usual road roller for the flattening out of barbed-wire entanglements. The technical section of the Engineers of the French Army conducted a series of experiments with a road roller equipped with a 20-horsepower gasoline engine. This tank, provided with an armored body somewhat similar to later-day tanks, was some 22 feet long, 7 feet wide, and 7 feet high, weighing about 10 tons. It was armed with three machine guns and was intended for a crew of eight men—two mechanics, a commander, and six fighters. When it came to getting over the battlefield and through barbed wire, the tank was not a success. In the first place, it could not operate over rough ground and over terrain which happened to be boggy; secondly, it only crushed down the barbed wire, which, after the passing of the tank, again rose in place to impede the infantry waves.

Courtesy of L'Illustration.

The Breton-Pretot Machine for Cutting Through Wire Entanglements

A MACHINE WHICH TUMBLED ALONG

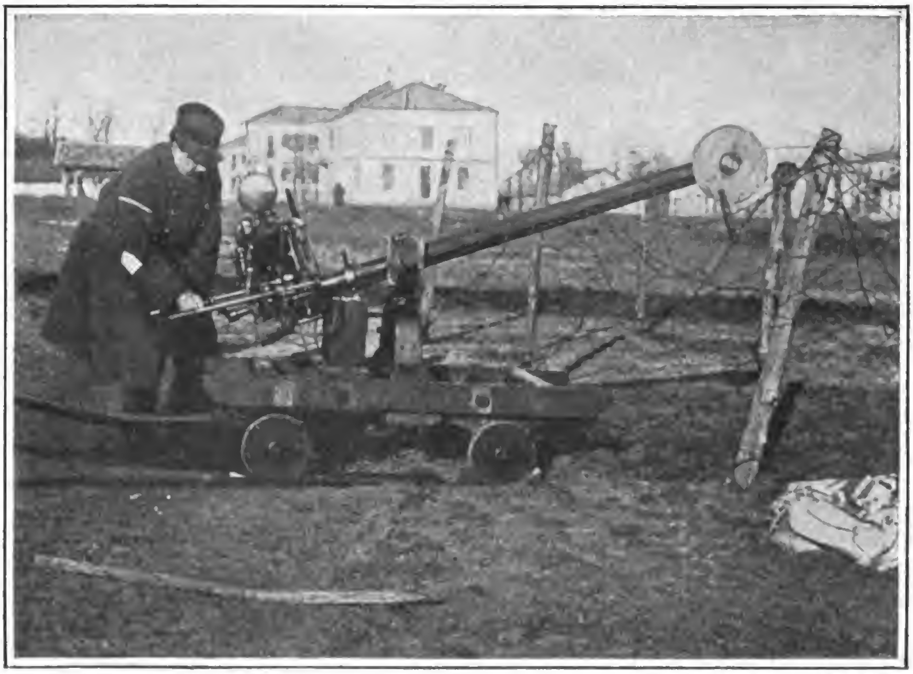
Another interesting ancestor of the tank was the machine of M. Boirault, which was examined by the French army authorities during the latter part of 1914. Essentially M. Boirault's tank, which is illustrated in the picture on page 155, will be seen to consist

of an iron structure carrying an 80-horsepower gasoline engine. The power plant, through a set of endless chains, served to drive a set of pinions which in turn operated the power-carrying member along the track laid down by the hexagonal framework. Thus each articulated section of the hexagonal framework was laid down in its proper turn on the ground, and the power-bearing unit rolled along on the short sections of track, just as the caterpillar tank lays down a continuous track for the body of the machine. Barbed-wire entanglements and shell holes and trenches were found to be readily spanned by this novel contrivance, which measured about 14 feet in height, 28 feet in length, and weighed about 30 tons. It had a speed of about two miles an hour.

In a series of experiments this novel tank proved quite practical for getting across battlefields; but it failed of acceptance because it could not be steered on its course. This objection was overcome by applying a screw jack, so that one side could be raised free of the ground so as to apply the driving power on the other side. Still, this procedure required too much time; and again, the tank was difficult to arm and still more difficult to protect with armor.

The technical section of the French Engineers then proceeded with the arming and armoring of agricultural tractors of the Filtz type, which were equipped with an inclined cutting member for hacking a way through barbed wide. Driven by a 45-horsepower engine, these tanks were capable of 7 to 9 miles an hour in either direction. In all, 10 such tanks were constructed, each armed with a single machine gun. Against taut wire, these tanks functioned pretty well; but when it came to slack wire they were of little value. During August, 1915, they were sent to the Fourth and Tenth French Armies for use in the field. On being tried near the battlefield, however, they proved unable to cover the rough terrain and were returned to the rear before the enemy ever saw them.

Still another attempt at the sudden destruction of barbed wire was the electric torpedo of Messrs. Gabet and Aubriot, which was intended for the transportation of some 200 to 400 pounds of high explosive to some suit-



Courtesy of L'Illustration.

A Device for Cutting Through Wire

able point in the enemy's barbed wire, which could then be blasted at the desired moment. For a mount, these inventors made use of a vehicle with triple caterpillar belts, driven by an electric motor. Power for the electric motor was conveyed through a special cable which was automatically laid as the diminutive tank traversed the battlefield.

In November, 1915, M. Gabet constructed an armored electric tank carrying either a machine gun or a 1½-inch quick firer, with a crew of two men. The electric power was supplied through a cable.

Inventors are prolific people, and never was this better illustrated than in the carrying out of the tank idea. Thus the inventors turned to other means of crossing the chaotic terrain of battlefields, this time using ordinary motor trucks. It was the automobile firm of Delaunay-Belleville which got up the ingenious arrangement of a motor truck which laid rails in front of its wheels, so that it could span trenches and shell holes, and after traversing these depressions, pick up the rails and carry them forward for the next depression.

WORK DONE BY THE ENGLISH

To the English belongs the credit of producing the first practical fighting machine of this type. Their first attempt was along the lines of a heavy armored car. This was not successful. Then they turned to the track-laying type of vehicle. It should be said here that the first man, probably, who suggested the idea of a large fighting vehicle, and who had a sufficiently clear grasp of the problem, was Lieut.-Col., later Brig.-Gen., Swinton, who had, several years before the war, broached the idea, and early in the war had argued its value and the tactics accompanying its use.

It remained for two others to make it mechanically practicable. Major Wilson of the British Army and Sir William Tritton, manufacturer of agricultural machinery, worked on the problem of the track-laying type, using the American type of track as a foundation. It seems that the really new feature of the large type of tank was carrying the track all the way around the body of the machine, and this design was the result of the joint labor of these two men. To negotiate wide trenches required a long machine. To climb over obstructions, particularly vertical walls, required great climbing ability at the front end. These requirements were both met in the long, rigid type of vehicle and the all-around track working up on a sloping front. These features, which were first combined by the two mentioned, marked the design of a new type of machine, which was a practical success from the start.

We have now seen how the main idea was conceived, almost in its entirety, by Swinton, and how this idea was made mechanically possible by Wilson and Tritton. Many an excellent thing, however, dies right at this stage for want of some one with faith in its usefulness and persistence in its creation to "put it over," as we say. This part of the task fell to two other officers, Sir E. d'Eyncourt and Lieut.-Col. Sir A. G. Stern. Too much credit cannot be given to them, for in the early days ninety-nine out of every hundred men looked upon the scheme as chimerical. They were unable to get much backing, but their faith and persistence finally were successful.

They were handicapped by the critical situation of English production resources at the time, and were allowed to use only such material as could be made available. Hence they had to use a heavy, stationary type of engine. A 100-horsepower unit was the largest avail-

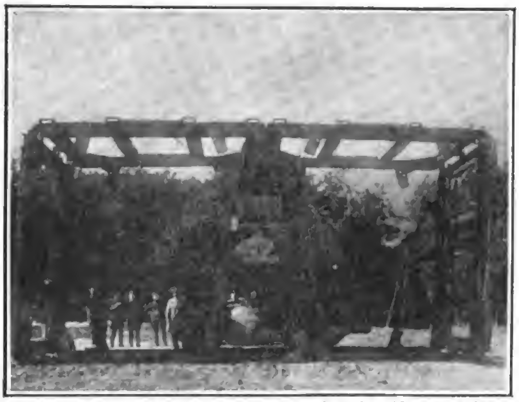
Courtesy of Scientific American.

A View of an Early French Predecessor of the Tank, Showing How the Jointed Six-Segmented Frame Around the Machine Was Laid as a Track For It to Run On

able. It was inadequate to give the best results, and many of the early difficulties of operation are traceable to lack of power. Some of the essentials of tank design were, naturally, not appreciated at first. Besides a lack of power, these earlier machines suffered from too great a unit ground pressure. This caused them often to get mired in soft mud.

THE TANKS IN ACTION

As noted above, even the military authorities did not fully understand how to use them. Usually, in the early days, they were sent "over the top" after an intense bombardment, which created a condition of terrain almost impassable for man, beast or machine. Consequently, while effective in some degree, their full value could not be attained. At Cambrai, in October, 1917, however, they had their first real chance. Here they were used in large numbers, and there was no preliminary bombardment. This fact meant surprise to the enemy and good terrain to operate on. The results were remarkable, and after that the most sceptical critic could have little to say. The subsequent reverse at Cambrai was in no wise connected with the employment of tanks. Two most interesting facts were the result of this attack. First, the saving in ammunition—which would have been used according to the old system in this one engagement—equaled the entire expense of the whole tank development up to that time. The tank squared financial accounts in this one engagement. Second, the finest, and supposedly the most impregnable, section of the famous Hindenburg line was crossed and captured with ease.



Courtesy of Scientific American.

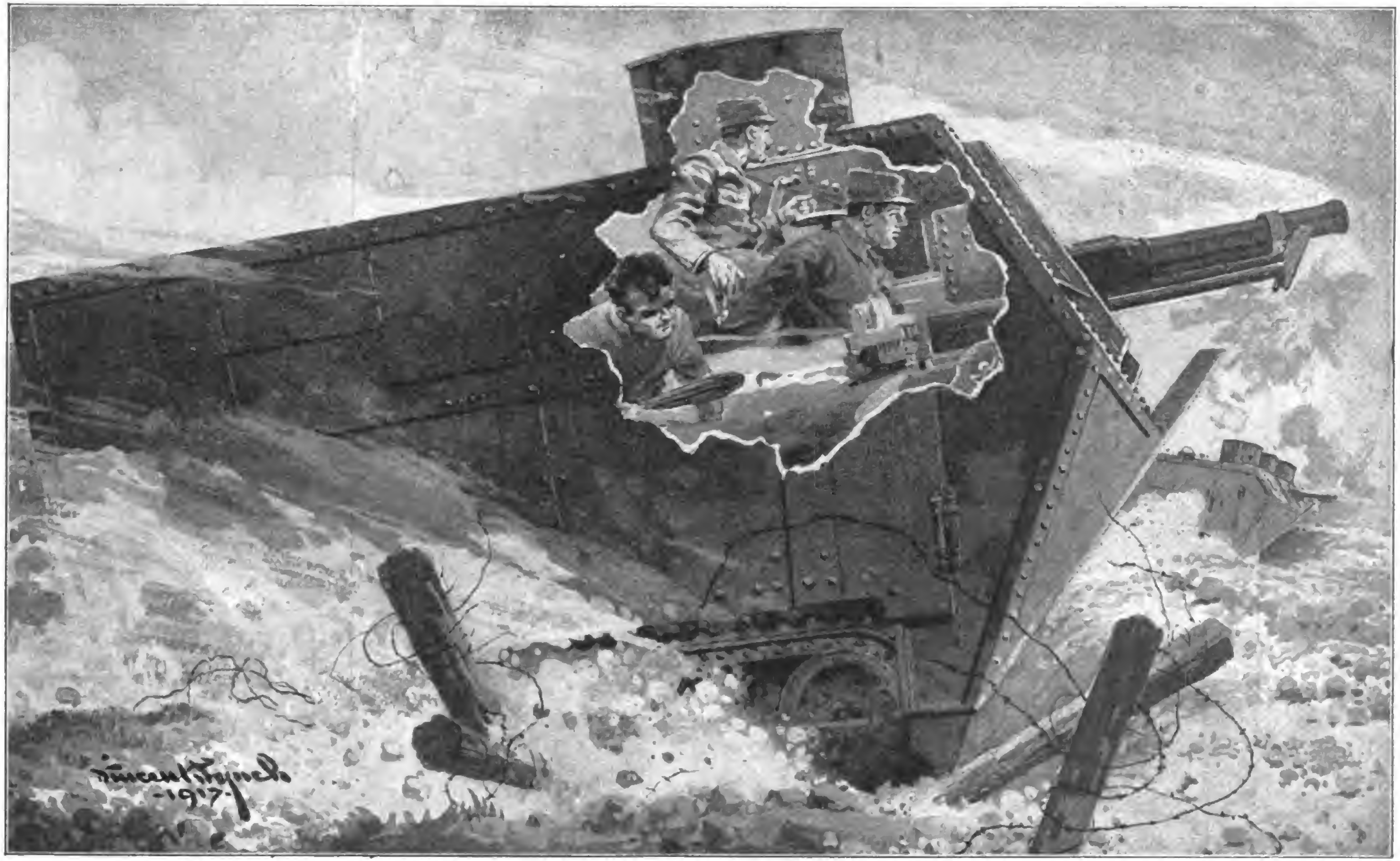
This View of What Was Practically the First Tank Shows the Frame Before It Was Shaped

The French had been busy, too, during this period. Only a little later than the English, they started developing a tank. They completed and put into the fighting line two machines, one made by the Schneider Company, and one by St. Chamond, the former being mechanically driven, while the latter was of the gas-electric type. Both were equipped with one 75-mm. gun and several machine guns in addition. These two machines were not, however, of the type of the English tank, with its all-around track. They were practically overgrown caterpillar tractors, with the necessary equipment mounted thereon. The bodies, in each case, extended, both fore and aft, considerably beyond the ends of the track proper, and also extended over the top of the tracks. This construction imposed serious limitations on the ability of the machines to negotiate bad terrain. Like the English tanks, they were somewhat lacking in power, which, taken together with the overhanging body features, seriously curtailed their action.

HOW THE "BABY" TANKS CAME INTO EXISTENCE

The French quickly arrived at the opinion that large tanks would not be successful, although subsequent developments with the English tank showed that in this respect they were much mistaken. In many ways, however, their decision was fortunate, in that it led them to turn their attention at once to the construction of a smaller machine. The result of this decision was the development by Louis Renault of a small two-man tank capable of considerable speed and possessed of a very fair amount of power per unit of weight. In many ways, the small Renault tank is a very remarkable machine. It will cross trenches up to 5 or 6 feet wide. It will climb grades of one in one, or 100 per cent. It will hold a speed on a level of about 5 miles per hour.

These tanks were built of two kinds, one equipped with a 37-mm. one-pounder semi-



Large French Tanks in Action

With the first one partly broken away to show the gun crew in action. These large tanks were used by the French during 1917, but were subsequently abandoned in favor of the baby tanks carrying two men only.

automatic gun, and the other with a Hotchkiss machine gun. These were used in about a 50-50 ratio in actual fighting.

The tracks were spring suspended, which enabled a speed of 5 or 6 miles per hour to be easily maintained without serious detriment to the machine. In fact, some of these machines, since equipped with more powerful engines, have successfully made 10 miles per hour across open territory.

It is very natural that the experience of the French with their first large tank should have convinced them that the small unit was the solution of the tank problem. It was equally natural that the success of the British with their large tank should have, at first, convinced them that the big tank was the solution. The results were extremely fortunate, in that they gave to the Allied fighting forces two kinds of tanks.

When the American Army entered the war both of the above lines of action were sufficiently well defined, so that the Americans decided to use both kinds, namely, a large and a small tank. For our small tank we adopted the Renault type. For our larger unit, we accepted a modified design of the large British tank, the design being a production of British and American ordnance engineers working jointly in the winter of 1917-18 in London.

Certain fairly well-defined essentials have gradually appeared in the matter of tank construction. They are as follows:

(1) Not less than 10 horse-power per ton of weight should be provided.

© *Underwood and Underwood.*

French Whippet Tanks

The French often attacked with scores of these deadly little land ships, with demoralizing effect on the enemy.

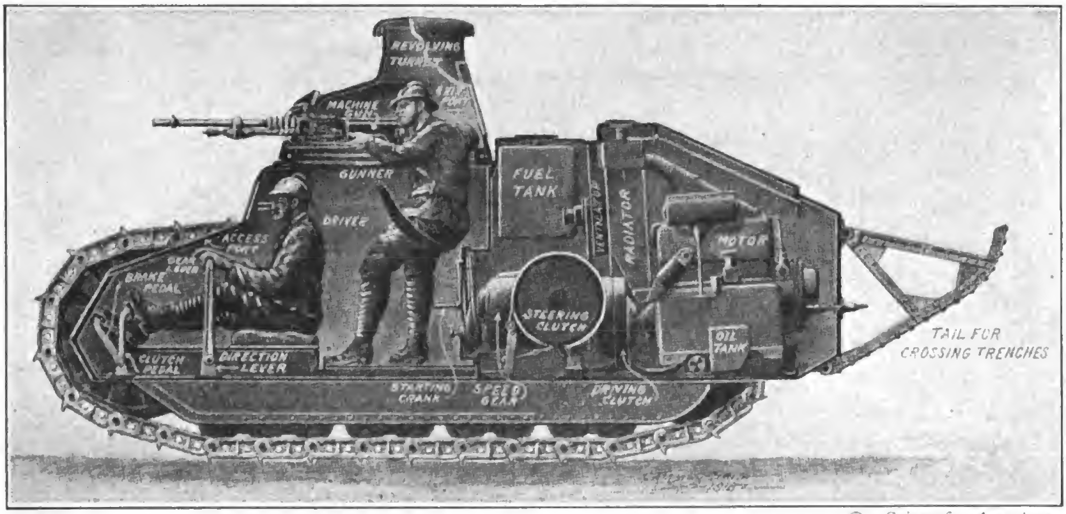
(2) The pressure per square inch between the track and the ground should not exceed 5 pounds per square inch.

(3) The tank should be entirely controlled, so far as its mechanical operation is concerned, by one man.

(4) The tank should be capable of making a speed of not less than 5 miles per hour on a level, and anything over that greatly increases the fighting ability of the machine.

(5) The only armor is that required to give protection against armor-piercing machine-gun ammunition.

A great deal has been said and thought about tanks with heavy armor, 2 and 3 inches thick, as a protection against moderately heavy artillery fire. Actual fighting conditions, however, have proved conclusively that tanks are rarely struck by direct artillery fire when in motion in action, as they do not present a very large target, and then only a moving one. Nearly all of the tank mortalities resulting from direct artillery hits have occurred when tanks were standing still, either awaiting orders or unable to move for mechanical reasons. Thus it has been demonstrated very conclusively that against artillery fire the best protection of the tank is its own speed and mobility and not the armor which it carries.



© Scientific American.

The Renault "Baby" Tank

Which was employed by the French and American armies in the closing battles of the World War.

THE GERMANS AND THEIR TANKS

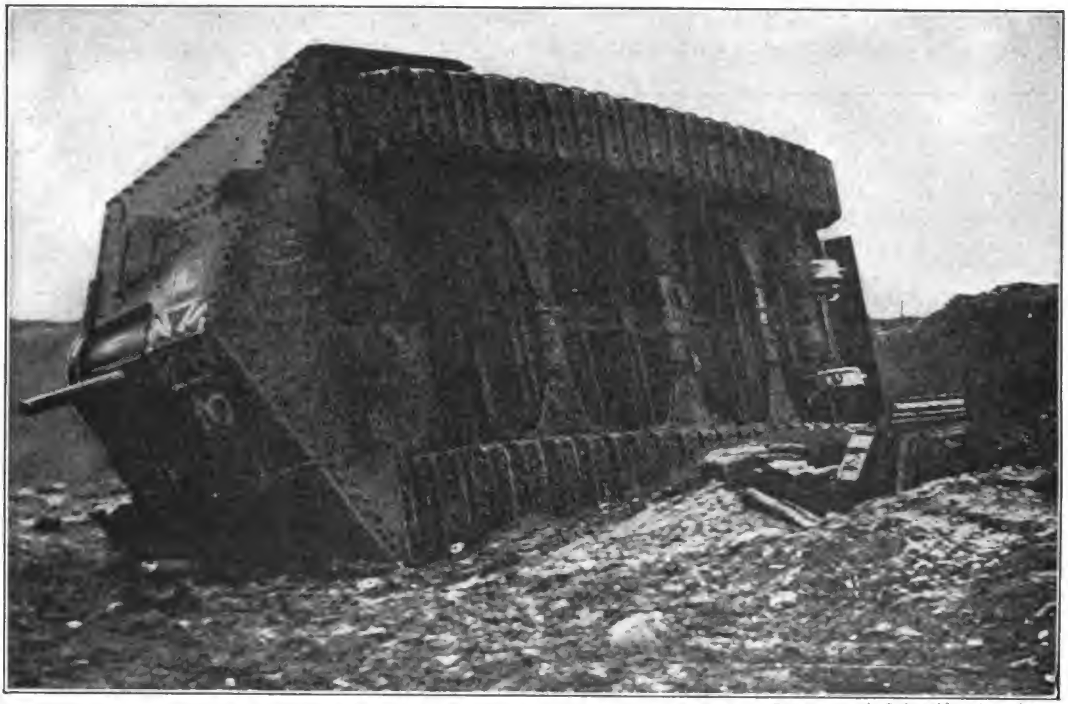
The much-heralded *Panzerkraftwagen,* or German tank, made its début in fair numbers in the great German attack on March 21, 1918, when the Germans were springing all their bag of tricks, including the long-range Paris guns. One of these tanks slipped into a stone quarry and turned over on its side, so that a subsequent advance by the French troops placed this German machine well within Allied lines where it could be studied at leisure.

The German version of the tank turned out to be a ponderous affair, quite in keeping with the *kolossal* tendencies of the Teutons. It weighed 45 tons, and carried a crew of eighteen. In general appearance it followed the French rather than the British design, but was larger than anything yet attempted by the Allies with the exception of the American steam-driven tank, which, as it was, was never sent into action.

Following the general practice of the French and British tank crews, the Germans named each *Panzerkraftwagen.* In the case of the first tank to be captured, it bore the name *Elfriede,* and carried on all sides the characteristic maltese cross of the German Air Service. Its armor plate varied from 1.2 inches for the front plates to .64 inch on the sides and .8 inch at the rear. The steel employed was applied in considerable thickness because of the evident lack of steel tempering materials in Germany, and that in turn made for a cumbersome, if not inefficient, tank.

As for armament, the German tank carried one 47-mm. or 1.85-inch rapid-fire cannon mounted for direct-fire ahead, and six machine guns mounted in pairs and placed at the sides and rear. The eighteen men of the crew had none too much room in this 23-foot tank, and the conditions during actual combat

were certainly not far from those of the proverbial sardines in a box. The conning tower, in which the driver sat, was entered from above and had hinged side shutters. But even at that moderate range observation was difficult because of structural defects. The crew got in and out of the steel box by means of two doors on either side. Every inch of space within the tank was utilized to the utmost; in fact, folding chairs were mounted on the inside of the doors and ropes were hanging from the ceiling in order to provide straps for the crew after the fashion of a crowded and lurching street car.



Courtesy of Scientific American.

A Large German Tank—Bottom View

Showing the caterpillar tread.

All in all, the *Panzerkraftwagen,* aside from its enclosed gear box, which reduced the possibility of the gears getting clogged with mud and dirt, presented no great improvement over French and British tanks which had already fallen into German hands. If anything, the German tank was more cumbersome through lack of materials, and therefore a poorer fighter.

No Italian tanks were used during the war, although certain automobile firms in Italy, particularly the Fiat organization, developed tanks. In Russia tanks were not used during the war proper, although in the civil war following the overthrow of the Kerensky government, tanks were used by the Russian forces in Siberia against the Reds or Bolsheviki with good effect. In the fighting about Odessa the French expeditionary forces made good use of two-man Renault tanks against the Bolsheviki. But as far as the Russians themselves are concerned, they did not develop a tank of their own.

It is very doubtful whether any supertank will be of a great deal of value, although one would be rash to make too positive a prediction. Anti-tank cannon, so called, have been developed by the Germans, but have never succeeded in doing anything serious. The supermachine gun, or a heavy-caliber rifle, up to perhaps ½-inch caliber, is the most serious attacking force that the tank has to defend itself against. Experiments on armor plate, however, indicate that defense against guns

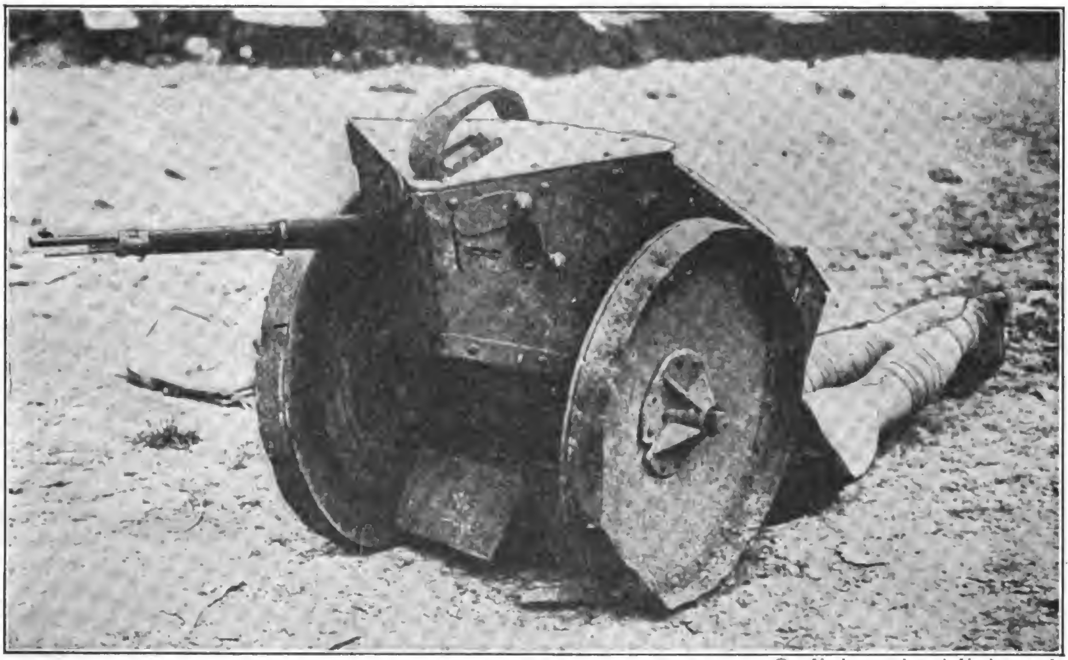
of this type can ultimately be secured with armor plate little thicker, if any, than that used at the present time. It might be stated here that the development and resisting power of light armor plate have recently been most gratifying, and indicate remarkable results possible in the near future.

The future development of the tank presents great possibilities. It must be fast, light on its feet, so to speak, and have large radius of action. It would appear that three sizes of tanks would be required:

First, the large one. This must be able to cross any trench that can be manned by the enemy. It is quite probable that large tanks will entirely preclude trench warfare. If so, the whole strategy of war will be changed. These large tanks will not be required in great numbers, but their presence is imperative;

Second, a medium-sized machine for following through after the large tanks and putting up a stiff fight. These machines must be tough fighters, and be present in considerable radius of action; and

Third, a small machine that will carry a driver and one gunner. It must be as small as possible to carry the two men. It must be simple in construction and very fast. It should be used in vast numbers, and be, in fact, a mechanical machine-gun cavalry. A thousand of these machines breaking through a gap made by their big brothers would completely disorganize the enemy's rear and produce a disaster.



A German Miniature Tank

This type of protection was used by the Germans as a sniping post.

In closing, it may be said that the tank is one of the few new things produced by the World War. It is only in the nursing-bottle stage. It will work a complete revolution in methods of making war. The side having the largest number of good fast tanks of the correct kind will always win. Its development has been almost a romance, and the future contains vastly more for it than the past.

GAS CLOUD AND GAS SHELL

The Major Tactics of Poison Warfare, and the Scientific Reasons for the Ultimate Prevalence of the Gas Shell

WHEN, where, and by whom the broad, general decision of the Germans to throw the rules of civilized warfare into the discard and employ poison gas was formulated, is something that would be of great interest to know, but something that the present generation is hardly likely to find out. Momentous as it was, this decision was a comparatively simple one to make, for it involved merely the single question of "yes" or "no." To the chemists and other technical men entrusted with the working out of the details, however, the matter was vastly more complicated.

If you are going to poison with gas a group of men a hundred yards or a mile away, it is necessary that you employ some means of delivering the gas to them. And the possibilities are just two. The gas may be liberated on a large scale when the wind is blowing in the desired direction, and allowed to blow across to the point for which it is intended; or it may be enclosed in a container of some sort and shot over. The first alternative is the gas cloud, the second the gas shell. It is still an open question whether the shell was employed in the earliest gas attacks, or whether it was entirely an afterthought; but certainly, in the beginning, the Germans relied altogether upon the gas cloud to produce an effect.

The clinching factor in the decision to adopt the cloud attack, if such a decision was made other than tacitly, was surely not the prevailing winds of Eastern France and Flanders. One could almost say that the wind in this part of the world sets always from the west. Indeed, so persistent is this eastward drift of the atmosphere that the Allied aerial service throughout the war was under a severe handicap. A German plane could fly over the Entente lines on one duty or another without much thought about getting back home; if there was just a little gas left when it came time to return to the Boche lines, the aviator could trust to the wind to see him safely through. But the British and French flyers had to go about their work with the thought ever in their minds that the wind would be dead against them on the homeward journey; and the number of instances in which the Allied aviator had to choose between leaving his task half done, and completing it at imminent risk of being brought down by lack of fuel before he could get back over his own lines, were legion.

WHAT ABOUT THE WIND?

But the thing which was so great a drawback in the aviation service turned out to be quite the reverse when it came to gas-cloud warfare. The combination of circumstances making it possible for the Germans to send over a gas cloud was comparatively a rare one. For gas diffuses with considerable rapidity across the wind; and the line between the two armies followed no straight course, but wound back and forth in the most intricate fashion. Now it does not pay to have stray bits of your own gas cloud wafted into projecting sections of your own front line. So in practice, it is found necessary to lay down the fixed rule that no gas cloud shall be released when the wind blows within forty degrees of any friendly position. If this rule is disregarded, the ordinary shifting from point to point of the wind will sooner or later bring about the gassing of some friendly troops.

It is not even enough that the wind blow in the correct direction, and hold fairly steady. Its velocity must also be favorable. Obviously if the current of air is not moving at a sufficiently lively clip, it will not take the gas away from the point of release fast enough, and the users of the new weapon

will find that they are gassing themselves instead of the other fellow. On the other hand, if the wind is too brisk, it carries the gas along too rapidly so that it is swept clear past the positions against which the attack is directed. The desirable wind velocity is anywhere from six to ten miles per hour.

Given all the conditions right according to the above outline and it is safe to launch a gas cloud against the enemy. But that is not the extent of the problem. The preparation for a cloud attack is a long and strenuous business. If you are going to release gas to be blown over to the enemy it is perfectly evident that you must release it from your own extreme front line. It would hardly do to gas half the depth of your own position in order to gas the enemy. So it is necessary to transport the gas from the factory to the general base, and from this point forward, from one distributing point to the next, and to the next, and to the next, until finally it is delivered in the front trenches.

Of course, the gas is put up in metal cylinders under heavy compression. This is necessary to save space; it is not feasible to allow the gas, in storage and transport, the same space, or anything like the same space, which it occupies after it is released. But gas under heavy pressure means heavy containers, able to resist the force exerted upon them by the gas. And heavy containers mean weight to be packed through the back areas, and into the trenches. Moreover, after the enemy once knows about your gas, it is necessary to place the cylinders—to bring them clear up from the rear and deposit them in their final resting places in the front line—without attracting his attention to the fact that anything unusual is going on. This is difficult, and sometimes even altogether out of the question, and at best it calls for a large number of specially trained men.

Courtesy of Scientific American.

Gas in Wrought-Iron Drums

Other drawbacks to the gas cloud are not hard to find. The gas used has to be an honest-to-goodness gas, a substance that becomes and remains a gas at ordinary temperatures. It has to be heavier than air, or it will not stay down on the ground, where the men whom it is hoped to gas are located; but it must not be too heavy, or it will not be blown and rolled along properly by the wind.

A BETTER WAY TO DO IT

One is, then, almost impelled to ask, "What is the sense of the gas cloud, anyhow?" It

is absolutely out of control; once the cylinders are opened and permitted to eject their contents into the air, the gas goes absolutely where the wind listeth. For a large part of the time it is not possible even to think of using the gas. The choice of materials is limited; the launching of a really vigorous attack, with a cylinder every yard or so along a considerable sector, is a monumental labor; everything seems to be against the gas attack when conducted in this manner.

That the judgment thus suggested is not altogether a faulty one is indicated by the fact that eventually, after the technique of gas-shell bombardment was perfected, the cloud was abandoned altogether except for its occasional use to keep the other fellow guessing. On every count of effectiveness, the shell scores far ahead of the cloud.

In the first place, it gives maximum concentration where it lands, among the enemy positions, rather than right in the front yard of the fellow who sets it off. The range of shell is many times the distance to which a cloud can be sent. Moreover, a shell can be put down precisely where it is wanted, as often as wanted and as long. You can get any desired concentration of shell at a given point by firing from various parts of your own lines. In a word, when you are firing shell filled with gas, you can give the enemy just the amount of gas you want him to have, in just the place you want him to have it, and for just the length of time you want him to have it. Not only that, but you can do it whenever you wish to, and not merely when a hundred-to-one chance on the weather comes true.

Externally the gas shell looks just like any other shell, except for the mark of identification in colored paint. This is, of course, necessary, for when you are using half a dozen different gases it is necessary to vary them at command. Incidentally, it may be mentioned here that the paint used in marking a gas shell of a given variety is so selected that it reacts chemically with the substance used inside its shell and changes color in this reaction. Then if there is a leaky shell the escaping gas acts as its own alarm.

The gas shell is shot from the same sort of a gun that shoots an ordinary shell, except that it may not weigh the same as a regular shell of the same caliber, so that a smaller propelling charge is called for to send it a given distance. Arrived at its destination, it blows up through the action of its fuse, quite like any well-behaved shell. But here the resemblance ceases.

HOW THE GAS SHELL WORKS

The ordinary high-explosive shell is designed to smash things up when it disrupts. So it has a very heavy disruptive charge, designed to do the maximum of damage. But the gas shell is not built that way. The poisonous matter is in a lead chamber inside the steel casing—for the gas would attack the steel, while the lead is impervious; and all that is desired is an explosion severe enough to smash up the steel and the lead, and leave enough energy over to atomize the contents nicely. It is to be emphasized that, unlike the cylinders from which the gas cloud is produced, the gas in the shell is not packed under compression, and so has no energy of its own; it escapes into the air with not the slightest inherent pressure; all the energy with which it is to be scattered has to come from the charge. It is also to be understood that too great a dispersion would be a loss rather than a gain. What is wanted is an effect of breaking up the gas into minute particles, and scattering it moderately about.

This brings us right to another tremendous advantage possessed by the shell over the cloud. Any kind of poisonous substance can be used in the shell; and if the charge be properly regulated, it will be properly atomized and spread out through the atmosphere. The majority of the gas shells are in fact filled with liquids, for without pressure you can pack more liquid into a given space than you can gas. And you can always depend upon the detonation of the shell to atomize the substance, whatever it be, and diffuse it in all directions. As one writer on the subject has said, you can gassify molasses in this way, with a sufficiently powerful explosion. The thing even applies to actual solids; these have been used in "gas shells."

If we thus employ in our gas shells a substance which, at ordinary temperatures, is divided in its allegiance between the liquid and the gaseous states, we shall cause the enemy

a great deal more embarrassment than if we had confined ourselves to regular gases. For a gas will sooner or later blow away and diffuse away, but a liquid will collect in all the low spots; and then, if it be an easily gassified liquid, it will vaporize at every slight increase of temperature, and condense again whenever it gets a bit cool. In this way, every morning's sun will cause a vast amount of noxious vapor to rise over a landscape that has been liberally gassed with liquid "poison gas." The enemy's daily life becomes then a daily battle with gas; and even though he suffers never a casualty, the trouble of protecting himself, and the resulting loss of fighting efficiency is, from the strict military standpoint, ample recompense for the expense and trouble of bombarding him in this fashion.

THE FINAL TRIUMPH OF SHELL OVER CLOUD

The actual history of gas warfare need not be discussed here. It is nevertheless in order to say that in the beginning the gas attack was delivered in the form of a cloud, with perhaps a slight use of shell. The element of surprise and unpreparedness of the Allies made the gas cloud an immense success on its first appearance in April, 1915, and moderately effective for some little time thereafter. But the inherent disadvantages of the gas cloud which have been pointed out brought it about that as soon as the Allies had once been made acquainted with the new weapon and had devised means to prevent its immediate gaining of its objective, it lost the greater part of its effectiveness. The shell attack was then brought forward as a substitute, and found to possess the conclusive advantages just enumerated.

So while in the beginning the gas shell was purely an incident in connection with the gas cloud, it was hardly more than six months, and certainly less than a year, before it usurped the major position in gas tactics. The cloud was not given up altogether, for it is effective when used once in a great while as a surprise measure and to keep the enemy guessing. No great knowledge of tactics is necessary to realize that after an interval of several months in which a given thing has not been tried, there is a very good chance of tak-

Courtesy of Scientific American.

Filling Shells With Mustard Gas

ing the enemy very much off his guard by reviving it temporarily. This is what the Germans did; but even on this basis the cloud attack was finally voted a failure, and was used for the last time late in 1917. As for the Allies, it can almost be said that they used it not at all. They followed at such a distance behind the German, in the use of gas, that they were able to derive no little profit from his initial experiences; and by the time the decision to retaliate with gas had been made, and the facilities for doing so had been provided, the gas shell had demonstrated its proper place in the warfare of poison.

THE PANORAMIC PERISCOPE

The last word in periscopes is the panoramic instrument. This is provided with an inner tube and an outer one. The outer tube carries a panoramic lens, and is so connected with the eye-piece that the entire sweep of the horizon is thrown before the observer's eye as a single plane circle, with blank center. Then in this blank space the lens system of the inner tube throws an enlarged view of the particular section of the sea toward which its restricted objective is directed. In this way the submarine can keep an eye out for pursuers from any direction while engaged in pursuit of its intended victim.

CHLORINE AND COMPANY

The Poison Gases that Were Used, and the Reasons that Governed the Choice

WHEN gas warfare was over three years old, the well-known chemical engineer, H. E. Howe, summarized admirably its purposes and methods as follows:

"Besides killing men, gas serves greatly to reduce the efficiency of an army by causing it to work in gas masks, tends to create confusion in ranks and transport, and makes ground untenable under certain conditions. Many gases have been used and the developments make it possible to apply all organic chemistry to this problem. As in all military tactics there is offense and defense, the problems in each case being highly specialized and quite different. The ideal of gas offense is a colorless, odorless, invisible, tasteless, highly toxic gas capable of being made in large quantities and of being easily compressed for transportation, having a high specific gravity, slow to react with chemicals, and offering the possibility of high concentration in the enemy's lines."

When we come to consider the various gases used during the war, we must, however, go back to the beginning and treat the subject chronologically. And in doing this, we must realize that the complete philosophy of gas warfare just outlined had by no means been developed. The idea of gas as a constant means of annoying the enemy was as yet unthought of. The gas attack was looked upon simply and solely as a convenient means of killing a great number of the enemy at one blow, so that resistance along a considerable sector should be completely paralyzed. The surprise element was to be paramount; the party to be gassed was not to have the slightest notion of what was to happen. Hence there was no particular need to seek for a gas that was not easily observable; the ruling factors were efficacy and manufacturing ease. Even the consideration of chemical inactivity which eventually got to be such a large one had little or no weight if the enemy did not know that he was about to be gassed. Efficacy was the paramount factor.

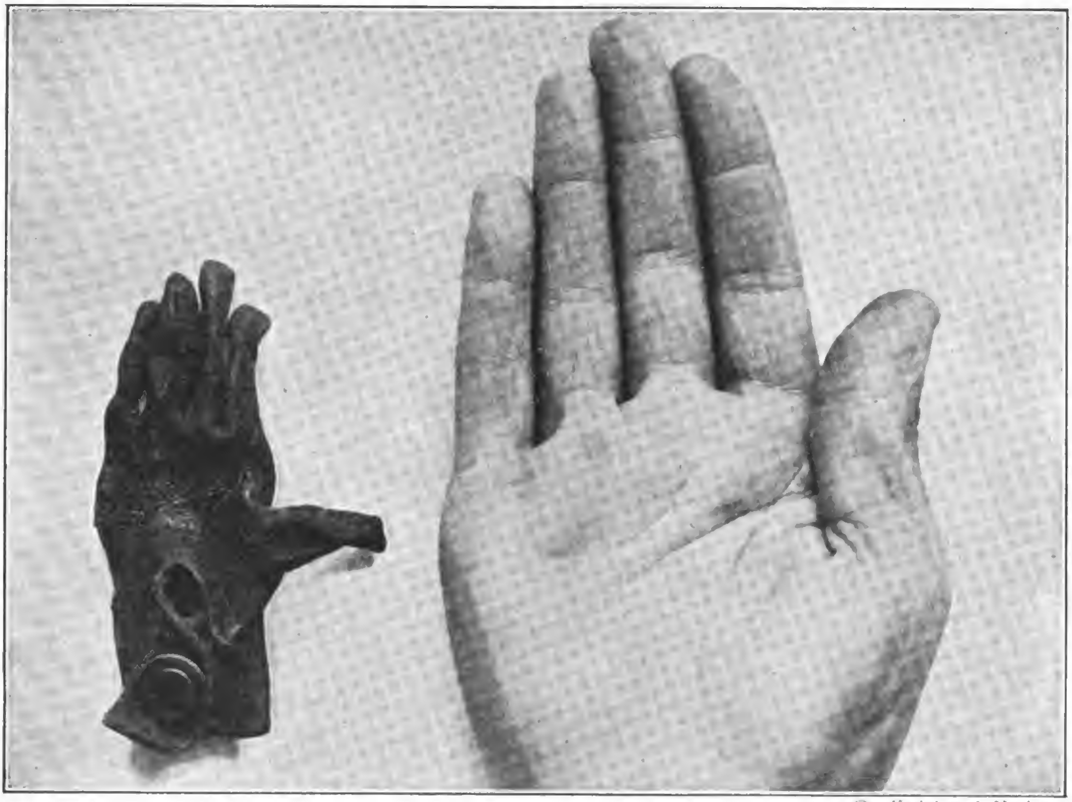
GAS POISONING

In the first place, it was necessary that the substance selected be poisonous, not merely asphyxiating. This is a distinction which may not mean much to the layman, but which is real indeed to the chemist. Carbon monoxide, for instance, kills because it sets up a chemical reaction within the blood that destroys this substance, so far as its power to support life is concerned. Chlorine, similarly, is a true poison, attacking the tissues with which it comes in contact. But nitrogen and carbon dioxide, on the other hand, are fatal in a wholly negative way. Just as we must have a certain amount of food to eat, so we must have a certain amount of oxygen to breathe; when we are submerged in an atmosphere of inert gases like those mentioned we simply do not get the oxygen, and the resultant asphyxiation is wholly analogous to the starvation which would overtake a man who was shut up in a place where he could get no food. It is practically the same thing as drowning, except that instead of its being a liquid that cuts off the oxygen supply, it is here a gas.

The process of drowning or asphyxiation takes place with comparative slowness. Particularly if a man be supplied with an atmosphere containing a great excess of inert gas, but not wholly lacking in oxygen, he will develop a headache and get strangling sensations in his chest and feel generally miserable, but he may go on living indefinitely. But all outdoors is a big place—a tremendously big place; and it is out of the question, in sending the enemy a dose of gas, to achieve more than a fairly heavy concentration of the

toxic matter in the normal oxygen-bearing atmosphere. The gas which you blow at him or shoot at him does not replace the air with which he is surrounded, it merely adds itself to that air. So while you might send enough asphyxiating gas over to the other fellow to make him uncomfortable, you could hardly hope to accomplish more than this. luckless human exposed to it. Of some gaseous poisons, a far smaller amount produces serious or even fatal results—sometimes as little as one part in a million.

So if we ask the chemist to send across No Man's Land enough asphyxiating gas to do serious harm to the fellows on the other side, he may well laugh at us. But if we propose



© Kadel and Herbert.

What Gas Did to the Kid Glove of a Soldier

A French second-lieutenant was gassed in the course of a battle during June, 1918. When he recovered at the hospital, he found one of his kid gloves in the shriveled condition here shown. The glove had dried up to about one-third its normal size, as indicated by his hand at the right.

With a real poison gas, however, a gas that burns or eats a man's insides out, or that sets up any regular chemical reaction leading swiftly to his death, it is possible to look for much more than this. To anyone but the trained chemist the small amounts of a deadly gas that will cause fatal results seem almost absurd. Air containing more than one part of carbon monoxide in 1,000 is dangerous; when the concentration approaches one in 500 it spells rapid coma and death for the that he create in the enemy trenches a sufficient concentration of some real poison to cause effects worth while, we are giving him a task well within his powers. He cannot alter completely the composition of the atmosphere about the enemy, taking away all the oxygen and substituting therefor a gas that will not support life; but it is no trick at all for him to present the foe with one part of deadly poison in a few hundred parts of air.

CHLORINE GAS

Now the Germans, when they launched their first poison offensive, had, as we have seen, no notion of making things merely unpleasant for the Allies. That phase of the gas warfare came later; at the beginning the idea was to kill the enemy, or render him absolutely defenseless, in large numbers. So the choice was narrowed down to a regular poison; and the *Herr Professoren* were merely obliged to decide which one. As pointed out in a previous chapter, it was necessary to have a gas heavier than air, so that it would stay with the enemy long enough to poison him. This ruled out the carbon monoxide which is everybody's first thought when poisonous gases are mentioned.

It was also necessary to have gas that could be manufactured on a big scale. It will help some if the raw materials are cheap as well as abundant; but Mars is a free spender, and will not be inclined to stick too hard on this point. The process of manufacture, however, must be easy and certain, so that there will be no difficulty in passing from laboratory procedures to commercial operations of magnitude. And when we have made all these demands, we have almost restricted the choice to chlorine.

Chlorine gas is a deadly poison. When it does not actually kill, a small dose reduces a man to a condition of gagging, strangling impotence. It is more than twice as heavy as air, so in an atmosphere of air it will go down and stay down. One part of chlorine in 10,000 of air leads to collapse in five minutes. And to the fact, familiar to every high school student, that chlorine in combination exists everywhere, may be added the circumstance that for years before the war Germany had been a large manufacturer of chemicals in the production of which chlorine actually occurs as a by-product, crying to be used. So it was with chlorine gas that the historic attack of April 22, 1915, was made; it was with chlorine gas that the Germans followed this up through the ensuing spring and summer; and it was with chlorine gas that the Allies retaliated when they realized that they must fight the devil with deviltry.

The chlorine attack, however, had two outstanding weaknesses, which, while not serious at first, grew with continued use. One of these was the frightfully obvious character of the chlorine cloud. This gas has an odor and a taste and a color that can be mistaken for the odor and the taste and the color of nothing else under the sun. There is absolutely no concealing the fact that there is a gas about, and that that gas is chlorine. So there is not the slightest chance that the fellow whom you are trying to gas will fail to recognize what is happening, and employ such protective measures as are at his disposal.

And right here lies the second weakness of chlorine. This gas is perfectly willing to combine chemically with a man and kill him; but it is not the least bit choosy, and would just as soon combine chemically with almost anything else in the world. It can fairly dispute with sulphuric acid the title of "universal reagent." And this means that the defense is never for long at a loss for some fairly adequate means of meeting the chlorine attack. Almost any free chemical will combine with the chlorine and render it harmless.

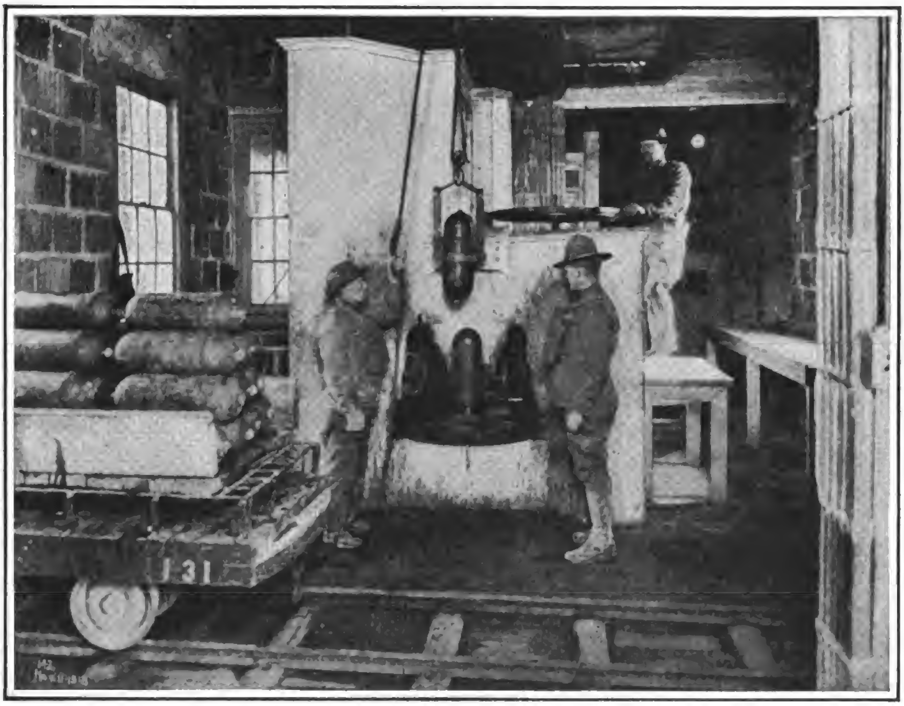
THE CAMOUFLAGED GAS CLOUD

When it developed that the Allies were actually succeeding in taking the sting out of the chlorine cloud along these lines, the Germans were not slow to shift their attack. Carbon monoxide would be ideal. It is colorless, odorless, tasteless; it leads to no pronounced symptoms; a man breathes it, with no consciousness that anything is wrong beyond a slight feeling of general depression, until he is at the very verge of collapse, and then he falls helpless before he can cry out or turn for aid. Carbon monoxide itself is out of the question because it is considerably lighter than air; but there is a related gas that fills the bill admirably.

This is carbonyl chloride, more familiarly known, perhaps, as phosgene. The name is deceptive in that it has nothing to do with phosphorus; it is formed by the combination of chlorine with carbon monoxide, and therefore is reasonably cheap and easy to make. Now it is a chemical compound, not a physical mixture, and it would accordingly not be strictly correct to say that being a combination of these two substances it shares their characteristics. But in the end, such a state-

ment would not be so far from offering a good picture of the facts.

Phosgene has not the same villainous odor and taste as chlorine; but it smells and tastes sufficiently like the simpler gas for all intents and purposes. Its color likewise is a fair imitation of that of chlorine. Accordingly, so far as immediate sensations and perceptions are concerned, there is little to choose between them, and little to distinguish between them. But there the resemblance ends.



Courtesy of Scientific Ameri...

Filling the Leaden Chambers of Shells with Phosgene

The effects of chlorine are immediate and marked. Those of phosgene are insidious and long delayed, so that when we say that it requires one part in 5,000 to produce rapid collapse we have told but half the story. Its general action is that of a depressant. This, of course, means heart failure or a tendency toward heart failure. And right here is where the little joker comes in. The delayed action of the gas is such that it does not lead to immediate weakness or collapse, or to any other symptom indicating that anything is wrong. But a few hours later the danger commences; for at any time from six to forty-eight hours after phosgene gassing, the heart is so on the ragged edge that the slightest little exercise will probably lead to immediate collapse and death. Men who have been gassed by phosgene without the slightest apparent effect have, after a good meal, or smoking a cigarette, or indulging in loud conversation, dropped dead in a most unaccountable fashion, apparently from nothing else than heart failure. If it were not so serious, it would be truly absurd what a little thing will cause the heart of a phosgene victim to stop beating.

This state of affairs gave the Hun a wonderful set-up. For when he began using phosgene, he did not use it alone, but rather in combination with chlorine gas—75 or 80 per cent. of the latter with 25 or 20 per cent. of the new substance. The result to which he looked forward may be roughly summarized as follows:

The Allied forces would observe the gas cloud; it would have all the characteristics of the usual chlorine cloud, and would be accepted as such. The customary protective

measures against chlorine would be put into effect, and would exclude the chlorine from the air breathed by the men. But the phosgene, unaffected by the chemicals used, would go right through and be breathed in freely by everybody. And then, during the next two days, as the delayed action got in its work, the entire Allied Army would drop dead individually and collectively, with utter unanimity. The only reason, in fact, why these expectations were not realized was that the British intelligence was in excellent order, so that the Allied command knew all about the phosgene for weeks before it made its first appearance, and were therefore fully prepared to meet it.

THE SUCCESSORS OF PHOSGENE

Of course it is not to be understood from this that the phosgene was a complete failure. In a vast number of individual cases, where instructions were not adequately given, or where they were disregarded, the effects of the phosgene were precisly as anticipated. And when the Allies got around to using this substance, it, of course, worked both ways; the man who would not take the delayed action seriously was pretty apt to have his connection with the war abruptly severed, whatever his nationality. But phosgene was not the complete and decisive success which it might well have been if its first use had been altogether a surprise.

Chlorine and phosgene were the only gases that were used to any extent in clouds. But by the time the gas shell came into general use the Germans had a chemical cousin of phosgene ready for service. This substance was not a gas at all, but a liquid; this was why it had to await the advent of the shell. Its chemical name is such a tremendous jawbreaker that it got the nickname of diphosgene, in allusion to its similarity to its predecessor. Its delayed action was if anything a bit more delayed, and undoubtedly more severe; and it was very persistent in its tendency to condense in puddles during the night and evaporate again in the morning. This characteristic always makes it possible to give the enemy a gassing that will last him several days on a comparatively small expenditure of shell.

With the possibility of using liquid poisons in shell, there was a good deal of attention bestowed upon the good old standby, prussic acid. This proved to be more or less of a delusion, however; and for the extraordinary reason that it was not poisonous enough. This, of course, refers not to the ability of a reasonable quantity of the acid to kill when taken in the ordinary fashion, but solely to the fact that, when atomized and administered as thus diluted with air, the greatest practicable concentration is not great enough. Chlorine and phosgene and diphosgene are effective when present in much smaller proportions than prussic acid, and so they got the call.

IRRITANT GASES TO THE FORE

It is not, however, to be understood that we have reached the end of the list of gases employed. After the poison campaign had been under way for a few months, it became clear that the defense would eventually win out, to the extent that only the careless and the unlucky members would be gassed. It then became in order for the attack to develop gases which, while not in themselves necessarily fatal in their effects, would make the work of defense more uncertain or more arduous or more disagreeable. It is quite customary to draw no line between the true poison gases, intended actually to kill, and the harassing gases, whose sole aim was to make existence as uncomfortable as possible for the enemy, and to lower his general morale and fighting efficiency; but we prefer here to make this distinction.

The Germans introduced the first of these substances in 1915, not so very long after the original gas cloud. It was used only in shells, and was what is known as a tear gas. Really it was not a gas at all, but the easily vaporized liquid xylyl bromide. This substance is a violent lachrymator, to use the technical term—which is to say, a very little of it makes strong men weep. Really, the effect of this material is ludicrous; if you walk into an atmosphere consisting of pure air plus .0001 *of one per cent* xylyl bromide, your eyes will water so profusely that you will be utterly unable to keep them open, and you will be thoroughly *hors du combat* for

some time. There are no after effects whatever; the man who gets a good dose of tear gas simply weeps himself into a state of temporary uselessness, from which he recovers quite rapidly when the irritant presence is removed. The tear gas was very effective at its inception, because the gas masks of the period did not pretend to protect the eyes from contact with the air—they were designed to do the only thing that up to that moment had been necessary, namely, to keep the gas content of the air from being *breathed*. But you don't have to breathe tear gas to get its benefit; you merely have to have contact between it and your eyes, in the infinitesimal proportions of one part in a million mentioned above.

MAKING THE ENEMY WEEP AND SNEEZE

Xylyl bromide, like all the other really effective gases, collects readily in liquid form, in the hollows and low spots, to vaporize again rather slowly. It is therefore possible to keep the whole area inhabited by the hostile forces pretty well drenched with it; and it really marks the beginning of the deliberate effort to keep the enemy constantly in his gas mask. It was but the first of a long series of irritants leading to this end. Some of these were tear gases of different properties; others gave different reactions, and affected different parts of the anatomy. Among the secondary tear gases we must mention one developed by the Germans which evaporated very quickly. The xylyl bromide was all right to use against the enemy's permanent habitations; but when you are bombarding an area preliminary to actual assault you require a gas that will be gone by the time you get there. So you use benzyl bromide.

Still another gas with lachrymatory effects is chlorpicrin. This, too, is a liquid at normal temperatures and so suitable only for use in shells. This needs to be pointed out specifically because in addition to its effect as a tear gas, this particular compound is poisonous on its own account. The discovery of a gas which has this double utility offers striking evidence of the scope which poison warfare affords the chemist.

After the lachrymators came the sternutators. Anyone who has ever held the proud position of bad boy in the village school will testify that there are certain substances whose presence in the air means that somebody is going to sneeze. You can't sneeze and fight at the same time, so the Germans made things unpleasant in the Allied trenches by adding to their other gases a most effective sneezing compound, the slightest whiff of which caused the most violent and prolonged spasms of sneezing. The particular use to which they seem to have tried hardest to put this was that of preparing the way for an attack with regular poison gas. It is obvious that anybody who is so unfortunate as to get the sneezing gas is going to get a proper dose of

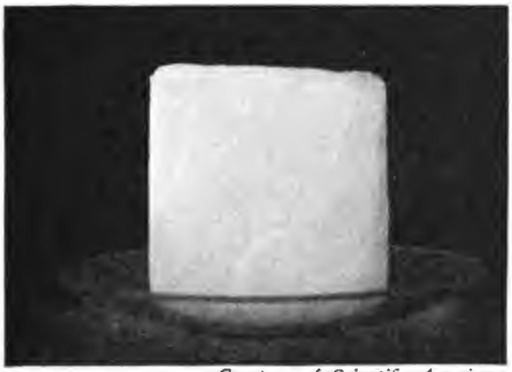
Courtesy of Scientific American.

Filling Hand Grenades

the chlorine or phosgene when it follows; for you can't defend yourself from poison gas in the midst of a sneezing spell.

While first and last the Germans alone employed more than twenty different gases, their general effects were for the most part similar to those of the leading gases described. Indeed, for more than a year the list of irritants on both sides was not extended to include anything beyond tear gas and sneezing gas. But in July of 1917 a new pest made its appearance—as usual, from the German side. It has nothing in the world to do with mustard, and it is a liquid; nevertheless the Tommies attached the name of mustard gas to it, and this name stuck. The justification was a fancied resemblance of its odor to that of mustard, though that odor has been de-

scribed in terms of everything else under the sun, from garlic to mouldy tobacco. This gas possesses some of the insidious features of phosgene, in that its effects are not immediate, but are felt only after exposure is a thing of several hours past. It is an irritant of a new sort, technically known as a vesicant. Unlike the tear gas and the sneezing gas, it affects no particular organ or locality; it simply reduces any living tissue with which it comes in contact to the condition of raw meat and blisters.



Courtesy of Scientific American.

Frozen Cube of Mustard Gas

THE KING OF ALL THE WAR GASES

Aside from this, it is not poisonous; but its vesicant effect is so extreme that there is a good deal of justification for those who insist on calling it an actual poison. If it is breathed, it inflames and blisters the lungs and the throat passages, causing the most acute suffering, and frequently leading to pneumonia. If it is swallowed, it behaves similarly toward the lining of the digestive tract. If it touches the skin, it does the same thing to it. Indeed, it often blisters badly through shirt or trousers or even through puttees or shoes, and, of course, it has a lachrymatory effect. The tales of men who have had to submit to amputation through getting a drop or two of mustard-gas liquid on a sleeve or a trouser-leg are fabrications; but that they are generally credited by men who have been exposed to the gas is excellent evidence of the virulent activity which it displays. Anybody who has had physical contact of any sort whatever with mustard gas is going to be a casualty, and an extremely unhappy one, for several weeks at least. If he has taken more than a little bit internally he will probably succumb. And the finest kind of a gassing can be picked up, through the delayed action, without ever realizing that there is mustard gas in the neighborhood.

The quality of sticking around which is such a valuable and sought-after one in poison gases is possessed to a superlative degree by this one. A man whose clothes have been slightly tainted by the vapor can enter a dugout and gas all the inhabitants thereof. On all these counts it can be seen that the presence of mustard gas makes it necessary for the soldier to go about his daily duties completely insulated from contact with the external atmosphere; and in bringing about this state of affairs it played the leading rôle.

This villainous stuff was of necessity adopted by the Allies without delay, and thousands of shells filled with it were shot off every day. The entire zone of conflict became a sink-hole of mustard-gas vapor; vegetation was utterly ruined; metal ornaments turned green over night; breech-blocks and other moving parts corroded so that they would refuse to function. Indeed, it is almost out of the question to depict the conditions of life created by the presence of the atrocious stuff. The men who were subjected to this sort of thing know what it was like—no one else can hope ever to know. And yet none of the belligerents were satisfied that mustard gas was the worst thing they could do; all were searching for a more deadly lethal dose. Right here in the United States, such a search was carried to a successful end. At the great electrical laboratory in Cleveland, facilities were put at the disposal of a group of volunteer workers, each of whom assumed liability for accidents. The result of this work was that at the time of the armistice we were prepared to begin manufacture of a new gas, of composition a permanent secret, and which would have been to mustard gas as mustard is to chlorine. In the same slight concentration in which mustard gas is merely a slight inconvenience, Lewisite would threaten immediate fatality. The Germans really saved themselves from the most harrowing experiences with this gas by calling off the fight just when they did.

IN THE POISON ZONE

Masks and Other Measures that Make Life Possible in the Gas-Drenched Areas at the Front

OF the Canadians and British and French Colonials exposed to the original gas attack, few indeed came off alive, although the gallant Canadians made a desperate attempt to counter-attack through the noxious cloud. With the exception of the irreducible minimum who had the knowledge and the presence of mind to muffle their faces in some good solid article of cloth, every man along a considerable length of the Allied line breathed chlorine; and every man who breathed it was a casualty. The whole Allied position was wiped out, and it will always remain more or less of a mystery just why the Germans did not go clear through to salt water. But the Allies did not wait for the enemy to try it again before considering protective measures; and, very fortunately, they were given time, before the wind made another attack possible, to work out a more or less satisfactory scheme for defense.

As a matter of fact, in theory, defense was simple enough. The man with whom strawberries disagree avoids being poisoned with strawberries by not eating them. Just so, the way to avoid being poisoned by chlorine gas is to avoid breathing it. If any device can be given the soldier, making it possible for him to breathe in the midst of a poisonous cloud without breathing in any of the cloud, he will not get poisoned.

There are two fundamentally distinct procedures after which such protection might be sought. One of them involves the use of the oxygen helmet, the other calls for a respirator. The former alternative involves putting the soldier's head into an air-tight receptacle, more or less like a diver's helmet, and supplying him with oxygen to breathe. This does not lead to all the difficulties which contemplation of the old-fashioned diving outfit would suggest. The old scheme of pumping air down to the diver is now being replaced by what is known as the self-contained helmet. The diver carries down with him an oxygen tank, which feeds good air to the space between his face and his helmet. The necessary supply of oxygen is made small, and danger of pollution of the breathing space by the exhaust gases from the lungs is eliminated by a sponge through which the diver exhales, and which is heavily charged with a chemical that takes up the carbon dioxide and makes the expired air fit to breathe over and over again. So the diver takes down with him a little artificial personally conducted atmosphere of his own, and he doesn't care a rap what sort of unbreathable stuff may be circulating outside his helmet. Just so his helmet is impervious to it, it may be poison gas quite as conveniently as salt water. So on general grounds it might appear that the technique of diving could be adapted to warfare, and the attempt made to send out soldiers thus equipped against gas clouds.

Scientifically, in fact, this scheme for an artificial atmosphere is the simple and logical way of solving the problem of poison gas. Practically, however, there are serious drawbacks. The oxygen helmet is a frightfully slow proposition from the manufacturing standpoint; a hasty substitute for the finished article cannot be improvised, and the Germans could probably have poisoned ninety per cent of the Allied forces while oxygen helmets for the other ten per cent were being made. Then the helmet is heavy and awkward beyond all sense; active work in it is too apt to make it spring a leak; a hostile bullet will ruin it, regardless of whether it strikes it in a part intimately associated with the process of breathing or not. So on every practical ground the idea of the oxygen helmet was quite out of the question, and the Allies of necessity fell back upon the respirator.

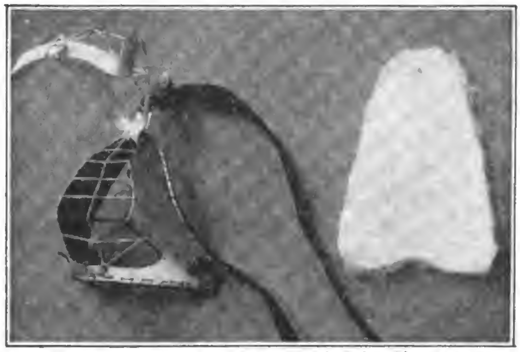
THE RESPIRATOR AND THE GAS MASK

This is something quite different. It aims, not at exclusion of the entire polluted atmosphere, but merely of the impurities. It passes the air from outside through a screen or a chamber of some sort, where by some physical or chemical process the poisonous elements are eliminated, leaving only good air to be breathed by the wearer. It is not a hermetically sealed compartment at all, it is merely a filter. It possesses the very great advantage that extremely crude improvisations will give fairly decent service as respirators while a standard type is being designed, adopted, manufactured in quantity and placed in use. And it was right under this count that the Allies were able to overcome the great initial advantage which the Germans enjoyed in being the first to use gas.

The initial attack was hardly over before provisional means of meeting a second one were under discussion—and under discussion everywhere—among the scientists at home, among the staff officers in France, right down to the private soldiers in the trenches, who originated and passed along all sorts of schemes, clever or stupid, for keeping out the gas. A wet rag over the face will keep out some of it; if this be well impregnated with damp earth it will give an even better performance; a pad of cotton batting or waste soaked in a solution of soda adds chemical action to physical and is good enough to be styled a satisfactory protection; a further refinement consists in supplementing the soda with photographer's "hypo" and glycerine. The French, for a time, even used a perforated metal nose-bag as a foundation for the cloth filter.

These devices were all used at the beginning, together with a vast number of less or doubtful value, and a good many that were utterly fatuous. Of course, in any event, the principal difference between effective and ineffective service lay in the items of training and discipline. Repeatedly, in the early days of gas offensives, of two units that had been equally exposed, one would come off unscathed while the other would be laid out to a man. The soldier had to be taught what the respirator was for, how to use it and especially how to keep it chemically active before and during a gas attack by proper dipping and wringing in the solution provided for the purpose—and above all he had to be taught that gas was a really serious matter, a thing that was equally effective against the seasoned campaigner in superb condition and the green rookie with no morale and no physique.

As suggested, the first unofficial respirators, and likewise the first types that were formally issued, were mere pads, with or without a supporting framework, designed to go over the mouth and nose and prevent the actual breathing of the worst of the poison. But it was not long before somebody—tradition has it that it was a British or Canadian sergeant—realized that all the air we breathe does not come to us in a straight line from directly in front of the nose and mouth, and that much greater efficiency would be got out of a respirator that covered the whole face. This idea led to the designing of the first helmet respirator—the first real gas mask—something to go on over the head and be fastened behind, and be slipped under the clothing at the neck and fastened there. The first mask was of flannel with a celluloid or mica window for visibility. It was soaked in the same combination of carbonate of soda with "hypo" and glycerine that had been employed in the respirators. This outfit was really an efficient protection; and as evidence that the Allies did fast work in meeting the gas menace, it may be stated that quantities



Courtesy of Scientific American.

When Gas Warfare Was In Its Infancy

So suddenly did gas warfare come upon the Allies, that they had little time to prepare for it. This simple piece of absorbent cotten was the first French effort at protection from gas.

of them were used in the attacks of May, 1915, barely five weeks after the poison cloud had made its maiden appearance. The user of such a mask had to be trained not to take it off when he began to feel stuffy inside it—in fact, when it was kept on for any period, that feeling was sufficiently strong to lead men to suppose that they had been gassed through the mask, and to snatch it off in panic. This was remedied to a great extent in a later model, wherein the flannel was of double thickness, the outer one alone being impregnated with the protective solution. The protection thus afforded from direct contact between the alkaline chemicals and the face not only was a big step forward in the item of

A Typical Gas Mask of the Comparatively Early Type

comfort but it also increased the effective life of the mask under a single dipping.

WHEN THE ATTACK SHIFTS

From the beginning the Allies realized that chlorine was but one of the gases which the Germans could use; and it was understood fully that if the masks were made with reference to protection from chlorine alone, a sudden shift to some other lethal substance would leave the men as badly off as they had been against the very first unheralded gas attack. There was some effort to canvass the field of available gases, but this was a hopeless guessing match. The switch to phosgene fortunately was known in advance, and was therefore adequately met. The British em-

French "Model M-2" Gas Mask

ployed carbolic acid dissolved in an excess of caustic soda; the French adopted sodium sulphanilide. Later all armies used sodium phenate. The Germans, there is some reason to believe, entertained good hopes that the Allies would fail to find adequate reagents for the phosgene, and, as a mater of fact, these are not numerous. But the ones named did very nicely.

With this incident it appeared that protection against gas was going to be a mighty serious matter. You could not rely upon always knowing beforehand when the enemy was about to start using something different. Yet to all appearances it was going to be necessary to keep up with him by introducing a new defensive reagent every time he sent over a new gas. And each mask would have to contain every one of these reagents, so as to protect against every gas. It would hardly do to ask a soldier to identify the particular gas that was coming over at a particular mo-

ment, and select the appropriate mask from a dozen hung about his waist. Moreover, it was questionable just how long the defense could keep up in this little game. Aside from the questions of bulk, etc., introduced, it is plain enough that if the materials in the fabric of the mask were, collectively, to constitute a universal reagent, they would probably react with one another and certainly

American "Model K. T." Gas Mask

with the carbon dioxide breathed out by the wearer.

Consideration of the latter item led to the designing of masks provided with a separate channel for outgoing breath, so that the soldier would exhale through a valve into the atmosphere, rather than into the mask itself. This met the situation for which it was got up; but there still remained the very pressing problem of making a mask that would be effective against any chemical which the enemy might take it into his head to use.

There was never any serious credit given the possibility of a single universal reagent, so that at first blush the necessity of providing a separate one for each toxic substance might seem inescapable. But eventually it began to be realized that chemical action was not the only way to prevent the gas from getting to the wearer of the mask. For instance, to take a very crude analogy, a bombardment of sugar would be stopped by a curtain of water, not because the water is impervious to the sugar (this would be the system of the diver's helmet), nor yet because the water combines chemically with the sugar (the original respirator system), but simply because the water would dissolve the sugar.

THE CHARCOAL CANISTER

So before we get too deeply into the chemical mire of gas defense, it might be well to inquire whether there is not some physical process of rendering the gas innocuous. And at once we realize that there probably is, for a great many liquids and solids (in powdered form) will absorb gases in much the same way that water dissolves sugar. The hopeless search for a universal reagent, then, gives place to a very hopeful search for a universal absorbent; and such a one is found in the familiar substance carbon. Finely divided carbon, in the form of charcoal, will absorb gas of almost any description until it is saturated. The saturation point is very high, the carbon absorbing many times its own weight of gas; and there is the saving circumstance that among the few gases which it does not absorb at all are the oxygen and nitrogen of the air. So air carrying a miscellaneous assortment of poison gases will be fit to breathe again if it be but passed through powdered charcoal. This brings us to the end of the war, so far as the protective substance in the mask is concerned. And if it reminds a good many of us of the campaigns for general conservation of fruit seeds, nut pits, etc., for gas masks, it may be appropriate to say that investigations under the U. S. Bureau of Mines showed conclusively that charcoal from these sources has the highest absorptive power of any that can be prepared.

With a mask covering his face reasonably well and his nose perfectly, so arranged that the air which he breathes passes through the charcoal in a container of indeterminate size attached to the mask, the soldier is fixed for any poison gas attack that may come his way. The advent of gas shell makes it necessary to design the mask so that it can be put on

in less time, but that is a mechanical detail that is comparatively easy to meet. But when the gas shells are found to contain gas that does not have to be breathed to get in its effects—tear gas, sneezing gas, etc.—that is something else. The good old flannel mask has to pass out with this development. It frequently did not pretend to cover the eyes; and even if it did, it is not air-tight or gas-tight; its principle is to let the air pass, and purify it *en route*. It is possible to do this with all the air that comes to the nose; but the air that comes to the eyes is more of a problem. In a word, the answer to tear gas must be a specially constructed mask with tight-fitting goggles—a helmet, in other words.

We have now a mask that has to protect the whole face, that has to be tight, that has to pass the incoming air, not through a wet rag, but over a mass of charcoal. When these requirements have all been met, we are pretty close to the final type of gas mask—a rubber and metal helmet, with goggles, big charcoal box separate from the helmet proper, and huge rubber hose connection. The only really large feature still lacking is the nose clip; and this is introduced when it is found, as gas becomes commoner and commoner, and the masked periods longer and longer, and the work to be done while masked more and more extensive and inclusive, that putting the nose out of commission and forcing the mask wearer to breathe in and out through his

Courtesy of American Chemical Society.

Types of Gas Masks Used by Allied, American and German Armies

Sitting, left to right: German, Russian and Italian gas masks; British, for motor truck drivers; British airplane respirator; experimental mask for metal facepiece. Center Row—First emergency method; British "P. H." helmet; British "box respirator;" French M-2 mask; French artillery mask; French "A. R. S." mask. Top row—Original American Navy mask; American Navy mask, final type; American "box respirator"; American A. T. mask; American K. T. mask, in production at end of war; American "Model 1919" mask—original and improved types.

mouth increases his endurance and comfort. It may be noted, as an aside, that the charcoal mask did away with the objection to the soldier breathing in and out the same way—charcoal does not absorb carbon dioxide.

GETTING GAS OUT AND KEEPING IT OUT

The introduction of mustard gas made no alteration necessary in the mask—it merely made its conscientious use more imperative. It gave a greater vogue to gloves, and encouraged the soldier to see that his mask went on tight; but that was all. The blistering effect of this gas was met by painting the skin with protective oils. However, the ever-increasing bombardment with gas shells of every variety, but all containing liquids which evaporated slowly and condensed again with alacrity, made it urgent to find some way of excluding the gas from the indoor regions of trench life—dugouts, huts, etc. A man must take off his mask to eat; and while it is not absolutely necessary that he take it off to sleep or to converse, he will probably think that it is. There really is no argument about it—the gas must be made to stay outdoors.

Diagram of Gas Mask

Showing the breathing arrangement and the nose clip.

For this purpose nothing was ever able to beat the double barrier of wet blankets in the doorway; and it was not long before blankets were regularly issued for this purpose. Everybody entering had to remember that he was passing through an air-lock, and make very sure that he did not raise the second blanket before he dropped the first. It is obvious enough that wet wool is not permeable by a gas except under pressure; so this measure was a complete succes.

A goodly part of the military existence, however, is spent outdoors; and while it turned out to be possible to wear the final types of gas masks for an incredible number of hours, and to do practically all the tasks of the day when thus clad, there are still good reasons for wanting to get sections of the trenches and of the general area behind them free from gas. Two ways presented themselves of attempting this: by fans and by chemical sprays. Both were successful to a moderate degree, but only to that degree. The fan used was a big affair with canvas blades, invented in England under the impression that it would suffice to blow the gas cloud back upon the Germans! Of course it was nowhere near powerful enough for this; but as a local measure it was used with rather satisfactory results. On the whole, though, the chemical attack upon standing gas is the most rational one. For every chemical there is some reagent; for every poison gas there is some substance that will combine to give a harmless compound. Only, when the poison liquid is present in such quantities that it can be shoveled out of hollows, it is not always easy to carry out, in the trenches, chemistry on a sufficiently large scale to do the trick. It is a good deal like trying to make a ton of chlorine in the laboratory of a small high school.

In closing this chapter, it is in order to say that the gas attack, as an instrument of destruction, has shown itself a monumental failure. You can give the enemy no end of bother and trial and tribulation with gas; you can cost him no end of time and money in the development and use of protective devices; you can force him to go about day after day masked, with the consequent diminution of his fighting effectiveness and lowering of his morale. But if his technical service is on the job with proper skill, and if proper instruction is given his men, and the teachings enforced

with proper discipline, the amount of actual damage that you can do him, as shown on the casualty list, is pitifully small. The careless man will get gassed every time, and there will be occasions when circumstances combine to make possible a certain amount of gas execution through surprise; but the general principle laid down by those in charge of gas defense is that the inherent value of gas is entirely in the direction of the inconvenience which it causes. No man need get gassed if he keeps his head and follows instructions.

POISON FOR AN ARMY

The Plant in Maryland from Which the United States Was to Have Made as Much Lethal Gas as All the Other Combatants Combined

THE manufacture of poison gas of any description on a scale large enough to give effect to its use involves a vast number of problems of engineering, of organization and of chemistry. These are about the same wherever the work of manufacture is carried out; the gas is the same wherever it is made; and the processes of making it are substantially identical in Germany, the British Isles, France and America.

Last in the war, the United States was easily first in the scale of her preparations for gas warfare. The total output of all the gas factories of Germany was never more than 30 tons per day; that of Britain and France combined was little if any more. But by January, 1919, had not the armistice intervened, the United States would have been delivering every day on the Western front over 200 tons of gas, ready for use against the Germans. Accordingly, it seems that an ample idea of what poison gas manufacture means can be had by surveying the work done in this country.

When the United States entered the war, although it was known that poison gas had been used by the enemy and was also used by our Allies, very little information was obtainable in America as to what materials were employed and how they were prepared. The Ordnance Departemnt was at this time charged with the responsibility of procuring all materials for the combatant departments of the Army. In November, 1917, it decided to establish on Gunpowder Neck, Maryland, which was then a part of the Aberdeen Proving Ground property, a small shell-filling plant. Ground was broken early in November. The property taken for this purpose was at that time planted in wheat for the spring

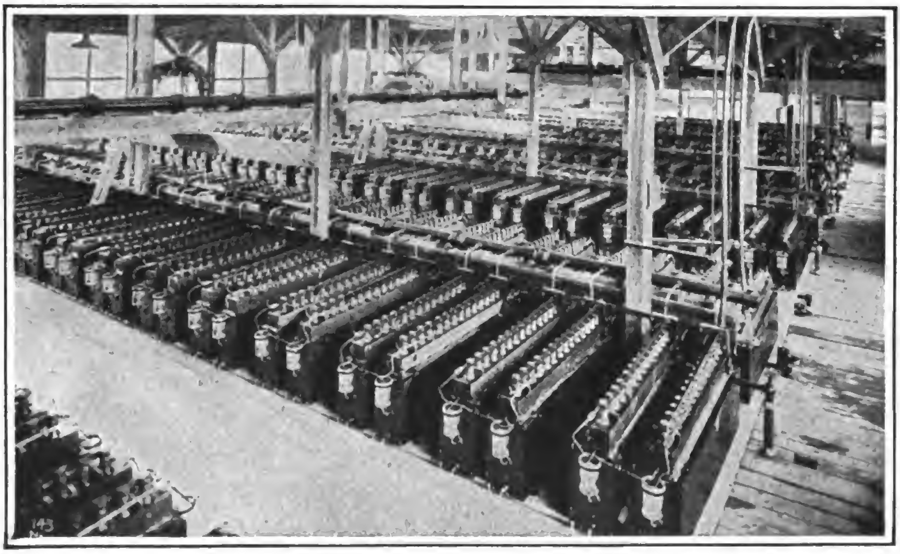
Courtesy of Scientific American.

General View of Chlorine Plant

crops, and no provision for housing men or for transportation of any kind existed. Railroad facilities were extended to the reservation from the Pennsylvania Railroad, and bunkhouses for a construction force were erected.

SMALL BEGINNINGS

It was then the intention to have the toxic gas itself manufactured by chemical manufacturers throughout the country and shipped to Gunpowder Neck for filling. Owing to the facts, first, that the poison gas materials were new in the sense of not being an established industry; second, that no one would want to manufacture them after the war and therefore the plant would be obsolete; and, third, the inherent danger of manufacturing toxic materials, it was soon determined that toxic materials could not be obtained throughout the country, however attractive were the offers, from a financial point of view, which the government made. Early in December, 1917, therefore, it was decided to erect at the shell-filling plant such chemical plants as would be necessary to furnish the toxic materials required for filling the shell. Designs for the chemical plants were ready late in December, 1917, and construction was started, notwithstanding the difficulties incident to a very severe winter. In order to obtain the greatest speed in the development of the processes necessary, the aid of such manufacturing concerns as were willing to undertake large-scale investigation was accepted. The two gases which it was then obvious would be required in large quantities were chlorpicrin and phosgene. The manufacture of chlorpicrin was begun on a relatively small scale at the plant of the American Synthetic Color Company, Stamford, Conn., while the manufacture of phosgene was undertaken at the plant of the Oldbury Electrochemical Company, at Niagara Falls, N. Y. The Trench Warfare Section of the Ordnance Department assumed responsibility for these developments. Between October, 1917, and February, 1918, however, gas manufacture had assumed much greater importance in Europe. It was in fact during this interval that the gas shell developed from an unsuccessful means of causing casualties into a very successful means of causing trouble and annoyance.



Courtesy of Scientific American.

Interior View of the Cell Building

Representatives of the French and British Governments were sent to America and were of the greatest possible help, not only with the information as to methods which they supplied, but also in furnishing an incentive for the work. By this time it was obvious that

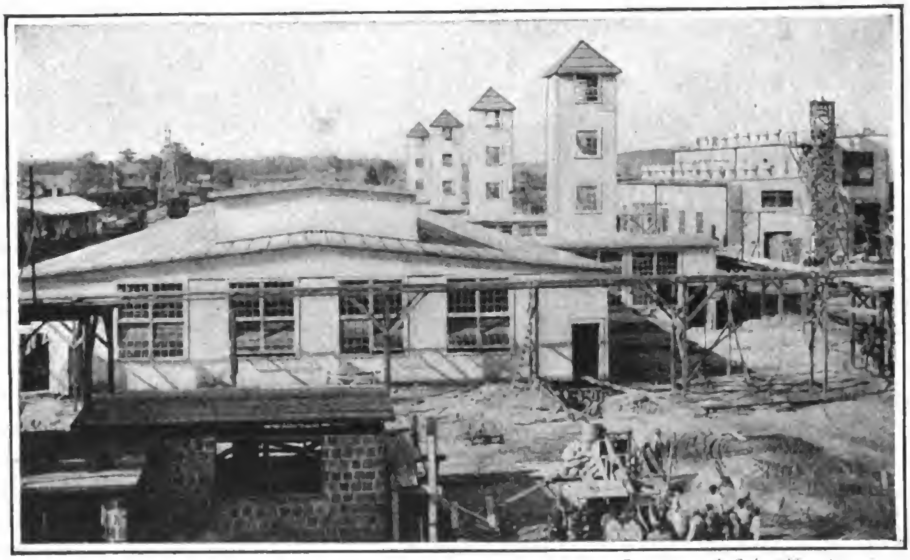
the government would be compelled to erect a large chlorine plant in order to supply this important raw material.

In January, 1919, things were not going as satisfactorily as desired, so Colonel William H. Walker, in civil life before the war a professor and director of industrial chemistry at Massachusetts Institute of Technology, and at the time in question chief of the Chemical Service Section and assistant director of Gas Service, was asked to take charge of the Gunpowder Neck project. He made it a separate bureau under the Ordnance Department—and later under the Chemical Warfare Service—and under his direction things at once began to hum.

The Edgewood Arsenal comprised the following seven departments:

First, an executive office, which was moved from Washington to Baltimore and was located in McCoy Hall, one of the old Johns Hopkins University buildings; second, the construction, maintenance, and stores division; third, the headquarters military organization; fourth, a military medical hospital; and then the great gas manufacturing plant proper, including, fifth, a chlorine plant for the manufacture of caustic soda and liquid chlorine; sixth, a chemical plant for the manufacture of toxic materials; and, seventh, a plant for filling the shells, Livens projector drums, Stokes mortar bombs, hand grenades, etc.

Apart from the construction of the plant itself, a large amount of important engineering work and other constructional work had to be done in housing and taking care of the civilian labor which was employed in putting up the buildings, etc., and in housing the operators, who numbered 6,500, and who were all enlisted men.



Courtesy of Scientific American.

Exterior View of the Cell Building

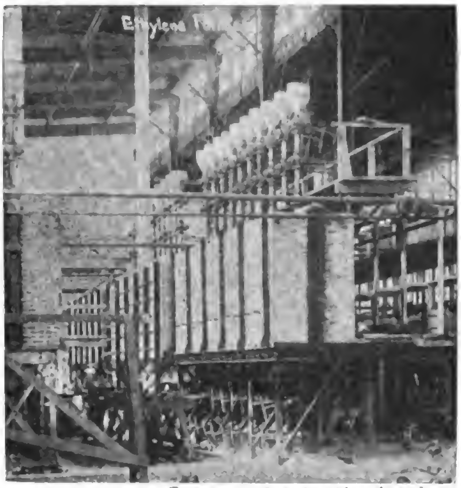
RAPID CONSTRUCTION OF THE PLANT

There was a hurry call for the construction of the gas plant, and the response made both by the engineering and chemical experts, who came out of civil life to asist the government in this emergency, and by the contractors and labor forces, forms one of the most creditable chapters in the history of our war achievements on this side of the Atlantic. Although ground was broken in the winter of 1917-18, it was not until January, 1918, that Colonel Walker was given a free hand, and it was due to his initiative and that of Lieutenant Colonel E. B. Ellicott, who had charge of construction, that the plant was built in such record time. The magnitude of the undertaking is seen from the following summary of some of the larger buildings which had to be put up:

Two cell buildings, 82 feet by 540 feet, a salt-treating building, 175 feet by 233 feet, evaporator and boiler house, 203 feet by 229 feet.

A drum-making building, 82 feet by 200 feet.

A caustic fusion building, 98¼ feet by 348 feet.



Courtesy of Scientific American.

Ethylene Furnaces

Twelve magazine buildings, 100 feet by 200 feet each.

A chlorine pipe trestle, 2,494 feet long, carrying three 8-inch pipes for the transfer of the chlorine from the chlorine plant to the chemical plant.

Permanent barracks buildings, comprising 16 two-story, tile-wall structures, each 50 feet by 200 feet, electrically lighted and with every accommodation, capable of housing 2,650 men.

A water-supply system, including a 1,300-foot dam, 6 feet high; an electric pumping system; two pipe lines, 10-inch and 12-inch, extending for 6,200 feet to a reservoir at an elevation of 155 feet, of a capacity of 1,600,000 gallons; two pipes, 10-inch and 14-inch, extending from the reservoir 6,000 feet to the Reservation, where the water was distributed to 11 miles of mains, 16 inches and 14 inches in diameter.

As showing the rapidity of the work, we may take the case of the construction of the chlorine plant, which consisted of two large buildings, each 82 feet by 540 feet and 24 feet high. Detailed plans were received on April 26th. Work was started on the cell building on May 1st, and the first of the four sections was ready to receive cells on May 27th, and the last section on June 11th.

Again, excavation for the salt-treating building was started on May 17th and on June 1st foundations were ready for six of the tanks, and all were completed before the 20 tanks that had been provided for arrived. After the tanks were up, overhead railroad tracks were built above them and with these preparations everything was in place ready for the first carload of salt on July 14th.

The chlorine gas was used at a chemical plant located some distance away, with a tide-water swamp intervening. The gas was piped, and to maintain the pipes at the proper elevation, a wood trestle, nearly half a mile long, was built between the chlorine plant and the chemical plant. Work on the trestle was started May 30th and the first pipe line was completed on July 4th.

Current for the plant was secured by tapping a source of supply 10 miles distant and bringing it in on overhead cables to an outdoor substation, containing a bank of three 3,333-

Courtesy of Scientific American.

Chlorine Plant Mixer

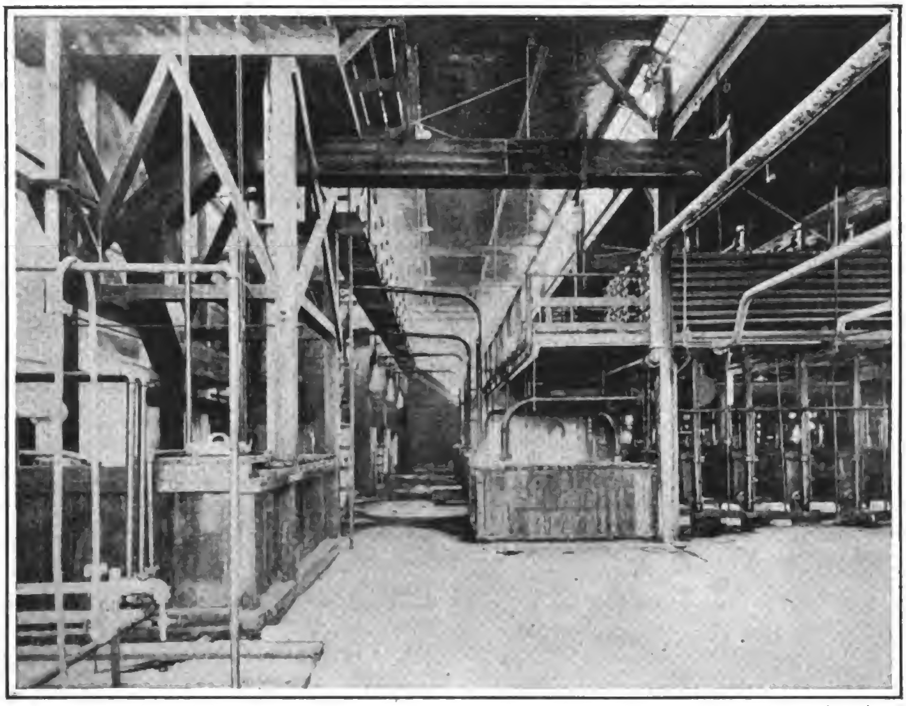
kilowatt transformers. This station was ready for service on July 1st, and while the above described work was in progress, enlisted men were assembling the chlorine cells and on July 4th enough cells had been completed to produce two and one-half tons of chlorine gas per day and deliver it at this rate to the chemical plant.

FIFTY TONS OF CHLORINE PER DAY

The developments at the chemical plant did not permit the use of the gas at this time and hence the plant did not go into operation until the first day of September, when the two and one-half ton unit was first used. But before the armistice was signed, the plant was ready to produce 50 tons of chlorine gas every 24 hours, although the greatest daily requirement at this time was 26 tons.

The chlorine plant included a shop building, cell houses, rotary converter substation, and salt-treating buildings. The salt-treating building, measuring 175 feet by 223 feet and 40 feet in height, involved heavy concrete work, both in the tank foundations and in the salt-treating tanks. There was also an extremely intricate system of piping connecting the tanks and the centrifugal pumps for handling the brine.

Current for the operation of the cell building was brought in by a high-tension transmission line, which was built across country to intersect the source of supply ten miles distant. The current was led to a rotary converter substation, and thence to the cell room.



Courtesy of Scientific American.

Mixer Unit in Phosgene Plant

The plant was designed with the view of increasing the capacity to 100 tons of chlorine gas per day when necessary, and early in the construction period, the order was received to build cell building No. 2, rotary converter building No. 2, and to purchase and install equipment duplicating that in the first unit. This additional work was proceeded with, and the buildings had been completed and a large part of the machinery was delivered and installed by November 11th. Had it not been for the stopping of work on November 12th, the second unit would have been placed in operation on January 1, 1919.

On July 15th, the chlorine plant was ready to deliver 2½ tons of gas daily to the chemical plant, and the rapidity of the work will be understood when we state that the site of the plant was selected only on March 27th, and in less than four months from that date it was ready to produce gas and deliver it by pipe line to a point about 2,500 feet distant from the place of production.

The chlorine is dried with sulphuric acid and conveyed in a steel-pipe line to the chemical plant where a portion is converted into phosgene, a portion to sulphur chloride, and a portion is liquefied. This liquefying plant had a capacity of 40 tons per 24 hours, compression being effected by a falling column of sulphuric acid. This liquid chlorine went almost exclusively to the Allies as raw material for further manufacture, although a portion was mixed with phosgene to be filled into cylinders for gas-cloud attacks. The sulphur chloride plant had a capacity of 35 tons per day and furnished a high grade of material without difficulty.

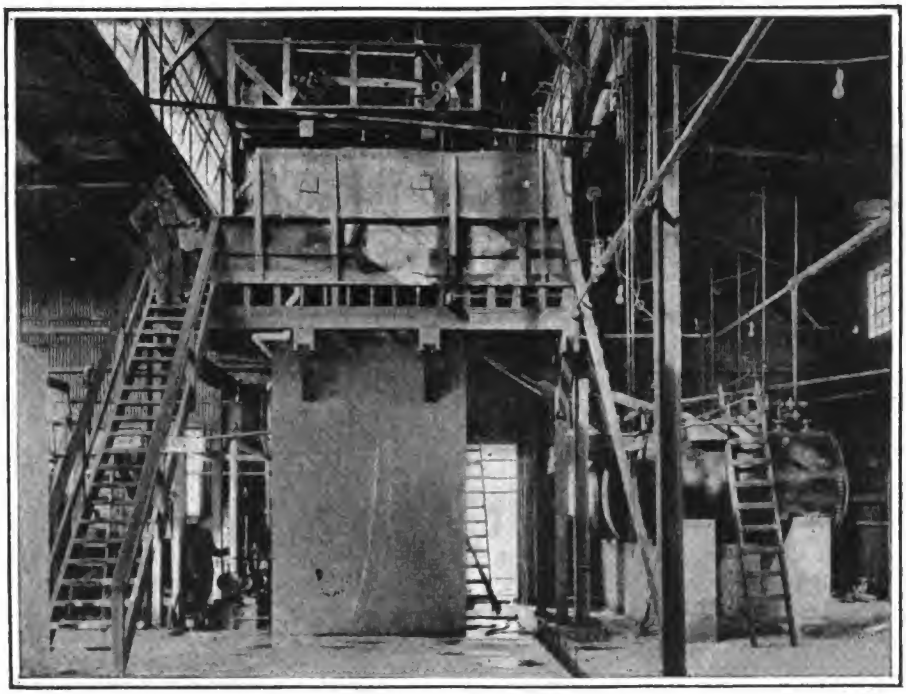
Courtesy of Scientific American.

Chlorpicrin Plant Mixer

PHOSGENE

The method of manufacturing phosgene as used at Edgewood was worked out in the laboratory of the Oldbury Electrochemical Company. Instructions from Europe were to the effect that the carbon monoxide could be made best by first producing oxygen from liquid air and using pure oxygen in a small water-cooled producer to make pure carbon monoxide. Obviously the great heat of reaction of oxygen and carbon must be carried away by the water rapidly enough to insure life of the converter. By combining the endothermic reaction of carbon dioxide and carbon with this exothermic reaction of oxygen and carbon, a standard U. G. I. gas producer can be employed and carbon monoxide made in very large quantities of high purity. The temperature of the reacting zone can be maintained as desired by regulating the relative amounts of oxygen and carbon dioxide used. The phosgene plant consisted, therefore, of a carbon dioxide plant, having a daily capacity of 125,000 cubic feet of pure carbon dioxide, an oxygen plant with a capacity of 200,000 cubic feet of oxygen per day, which when used with four producers gave a daily production of 400,000 cubic feet of carbon monoxide. When carbon monoxide and chlorine are passed over a carbon catalyzer, phosgene is produced with the generation of much heat. It is necessary, therefore, to maintain by cooling a definite temperature. The reaction is practically complete and the phosgene is liquefied by passing through condensing coils immersed in refrigerated brine. During the late war phosgene was employed in filling the standard caliber gas shell, Stokes mortar bombs, and Livens projector bombs. It was also shipped to the Allies, for their filling plants, in large quantities in wrought iron drums containing 1,700 pounds. The demonstrated capacity of the plant reached 40 tons

per 24-hour day. Two additional units were almost completed which would have brought the total capacity to 80 tons per day. Phosgene was manufactured also in the government plant operated by the Oldbury Electrochemical Company, where the carbon monoxide issuing from the phosphorus furnaces was utilized. The capacity of this plant was 10 tons per day and used partly in filling projectiles at the plant, and partly in containers for shipping abroad. The Bound Brook, N. J., plant of Frank Hemingway, Incorporated, had a capacity of five tons per day. This product went almost exclusively to the Allies in bulk.



Courtesy of Scientific American.

The Latest Mustard Gas Unit

THE MANUFACTURER OF CHLORPICRIN

Also at Edgewood there was built a very complete plant for the manufacture of chlorpicrin, which not only has a strong lachrymatory effect, but also is a powerful lethal gas. Because chlorpicrin is liquid at normal temperature and pressure, it is necessary to use in projectiles filled with this gas a rather stronger explosive charge than is required when a real gas such as phosgene is used as the filler. Chlorpicrin is produced by the reaction of bleaching powder upon calcium picrate, the reaction taking place in wrought-iron digesters which are furnished with condensers. So long as the temperature of the reaction remains within the very definite and limited range in which the chlorine in the bleaching powders reacts upon the calcium picrate, the reaction takes place very evenly. But if the temperature passes outside of these limits, the bleaching powder liberates oxygen in place of chlorine and the entire mixture foams over into the condenser.

When the reaction takes place as intended, the chlorpicrin distils out and is separated from the accompanying water after being conveyed to settling tanks and allowed to stand in them for a few days. At a plant which the government employed at Stamford, Conn., the picric acid was produced from phenol and was used directly in making chlorpicrin. Picric acid for the Edgewood plant was provided from other government plants, a great portion of the picric acid thus employed having been that rejected for other

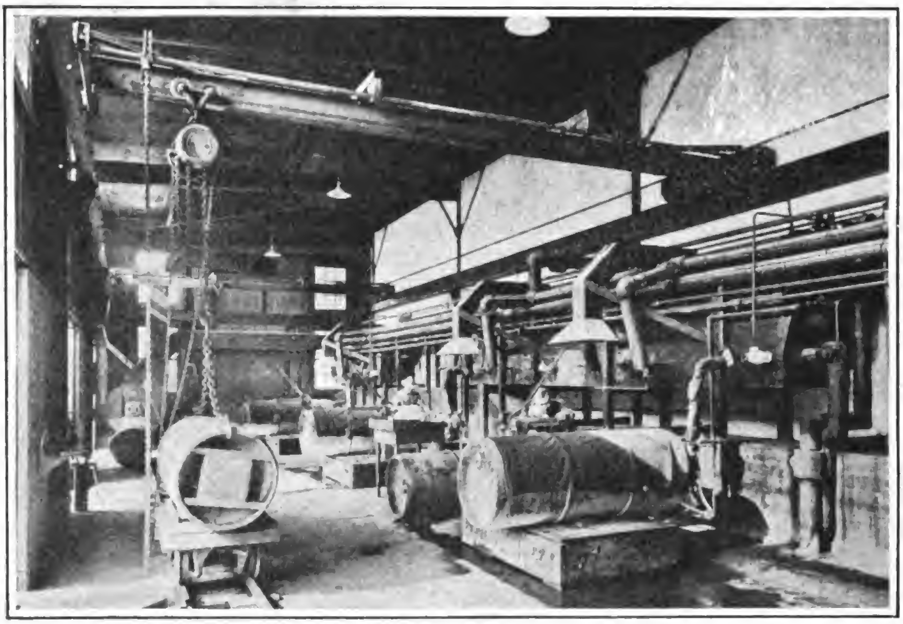
uses by both the United States and the Allied governments on account of excessive lead content.

Chlorpicrin was used as a filler for all kinds of projectiles, the shells sometimes being filled entirely with chlorpicrin and at other times containing a mixture of chlorpicrin and phosgene or stannic chloride.

MUSTARD GAS

Mustard gas is produced by passing dry, pure ethylene into sulphur chloride at a temperature maintained within very narrow limits. The reaction vessel can be either cast iron or wrought iron lined with lead. The reaction is highly exothermic—*i. e.,* it gives off heat rather than absorbing it—and a large cooling surface must be maintained. The reaction is a cranky one and is accompanied by destructive side-reactions which are difficult to control. When a batch "goes wild" great volumes of hydrochloric acid are given off, accompanied by highly toxic gases of an unknown composition. As the gas is strongly lachrymatory, such accidents produce great discomfort. Under certain conditions free sulphur is deposited which usually appears as a eutectic with mustard gas, giving a viscous mixture which is mechanically very difficult to handle.

Mustard gas was filled into shell of all calibers and was sent to the Allies in bulk in large quantities. Starting with 1½ tons per day in July, the production was constantly increased, until in the end the plant had a demonstrated capacity of somewhat over 30 tons per day. Other units to have been completed woud have brought the capacity of this plant to 80 tons per day. In order that other sources of mustard gas could be available in case of accident at Edgewood, or were a greater supply demanded, this Arsenal constructed a plant with a capacity of 25 tons per day at the plant of Zinsser & Company, Hastings-on-Hudson. A second plant of 50 tons capacity was nearing completion at the works of the National Aniline and Chemical Company, Buffalo, N. Y.



Courtesy of Scientific American.

Filling a 1700-Pound Container

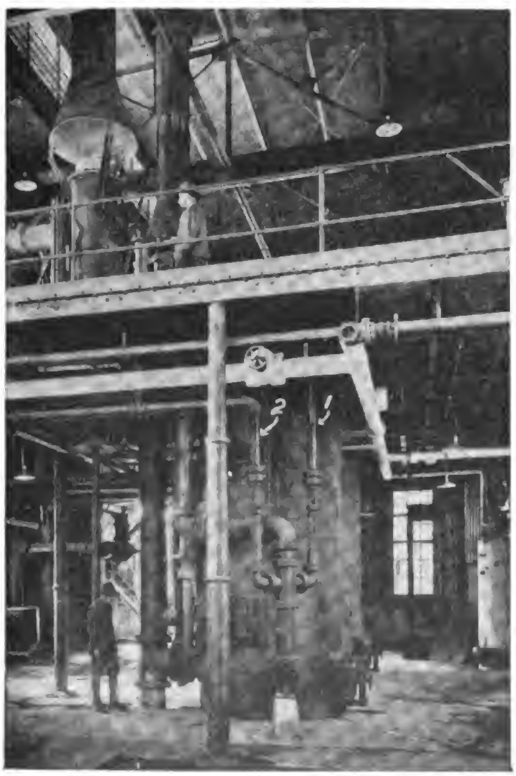
THE SHELL-FILLING PLANT

The shells and bombs for carrying the gas into the enemy's trenches and into the terrain back of his front lines were shipped to Edgewood from the various shell plants and stored

in large dumps, from which they were taken as needed to the shell-filling plant, which was designed for the filling of shells of all calibers from 75 mm. to 240 mm. In order to make sure that the phosgene was maintained in a liquid condition at atmospheric pressure, the shell-filling plant was equipped with the necessary refrigerating appliances for reducing the temperature of the phosgene and of the shells. The shells to be filled were brought by conveyors through rooms in which the temperature was 0° F. and unloaded in front of the filling machine at a temperature well below the boiling point of the gas. The filling machine was arranged to fill six-shells at a time and the filling was done within a glass-enclosed cabinet. The liquid phosgene was delivered by small tubes into containers of the exact capacity of the shells, which were filled six at a time. The shells were brought into the cabinet on a trolley, and they were so placed that the heads of the shells registered correctly with the outlet of the flasks above. The cabinet was so aranged that the discharge of the contents of the flasks to the shells could be regulated by an operator outside the cabinet, and means were provided by which not even a drop of the liquid could fall outside of the shells. The shells were closed by compressed-air motors. As soon as the set of six was filled, the trolley passed out of the cabinet, taking the filled shells with it.

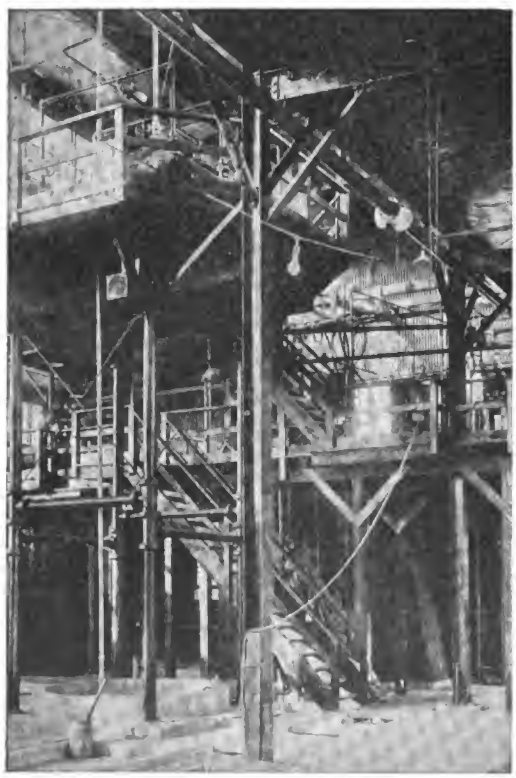
The next operation is that of painting the shells with certain colored bandings which show at a glance the nature of their contents. Painting and striping were done on an endless conveyor, which carried the filled shells in front of a number of operators, each of whom performed his share of the work. It is needless to say that every part of the plant for shell-filling was most carefully ventilated, the tail-gas being washed in lofty stone-ware towers which were constructed on the lines of the standard silo.

The shell-filling plant had a capacity in 24 hours of filling 80,000 77 mm. shells, 10,000 4.7 mm., 50,000 155 mm. and 4,000 8-inch shells.



Courtesy of Scientific American.

Carbon Monoxide Producer



Courtesy of Scientific American.

The Latest Mustard Gas Unit

PART III. THE WAR IN THE SKIES AND UNDER THE SEA

TAKING THE WAR INTO THE SKIES

How the Airplane and the Dirigible Were Developed Into Efficient Fighting Machines in the Course of the Long War

THE opening days of the war found the airplane hardly ready for aerial warfare in the present sense of that term. It was a delicate craft, suitable for flying only when the weather conditions were ideal. It did not carry machine guns or other weapons of defense and offense. It could only be built in small sizes, suitable for carrying a very limited load and one or two passengers. The engine was generally very unreliable, and a pilot was apt to be obliged to come down in enemy-held territory every time he started on a flight.

IMPROVEMENT THROUGH COMPULSION

Early in the war the value of the airplane as a super-scout became manifest. Indeed, to an airman perched several thousand feet aloft nothing of military consequence could be kept secret. Troop movements, the installing of additional batteries, train movements, the digging of new trench elements, the building of additional hospitals, ammunition dumps—all these things are plainly visible to the airman aloft, or at least were visible before camouflage became a fine art.

So each side hastened to use all its available airplanes for spying on the enemy. The French had a fair number of machines available, but these were not of a suitable military type. The British had but a handful of machines, militarily speaking. Only the Germans had a large number of machines especially designed for military purposes.

The first few months witnessed such activity on the ground that no one had much time to worry about aviators and their activities. Then, when the armies settled down into their trenches, the generals began to realize that enemy airmen were seriously interfering with their plans. They were making surprise moves impossible—and surprise has always been the main ingredient of successful strategy. So the generals ordered the enemy airmen to be stopped from spying, and that is what brought aerial fighting into existence.

At first enemy airmen were opposed by anti-aircraft fire, but this did not and never has proved very successful. Then the airmen took pot shots at one another with pistols and rifles. Soon one airman came along with a machine gun mounted on his plane, and others followed suit. That, in brief, started the whole matter of armed planes and aerial battles.

The French and British during 1914 and 1915 made use of the Farman type of airplane, which is a "pusher." The propeller in this type of machine is behind, and the observer sits out in front of the wings as distinguished from the "tractor," in which the propeller is in front and the observer sits to the rear of the wings. Obviously, the only place to mount the machine gun was in front, so that it could be operated by the observer while the pilot behind attended to the running of the good ship.

Meanwhile the Germans made use of a tractor, and since the propeller was in the way, they were obliged to mount their machine gun in the rear cockpit, next to the observer. The Allied airmen were able to fire their machine gun through a horizontal arc of almost 160 degrees in front, while the Germans were able to fire their piece through a similar range at the rear. The former had a serious "dead angle" or "blind spot" in the rear. The lat-

ter had a "dead angle" in front, which made it impossible for them to fire on an enemy machine in front. In either case the handicap was too great to survive more than a short time. Evidently, one was destined to be a pursuer while the other was obliged to be the pursued if an exchange of shots was to take place; the rôles were absolutely fixed.

Still another disadvantage was presented in inaccurate firing. With the gun firing at an angle with relation to the direction of flight, accuracy was affected by two forces: first, the lateral initial velocity due to the speed of the airplane; second, the side wind on the bullet also due to the speed of the airplane. All these factors went far in keeping the aerial casualties low during 1914 and 1915.

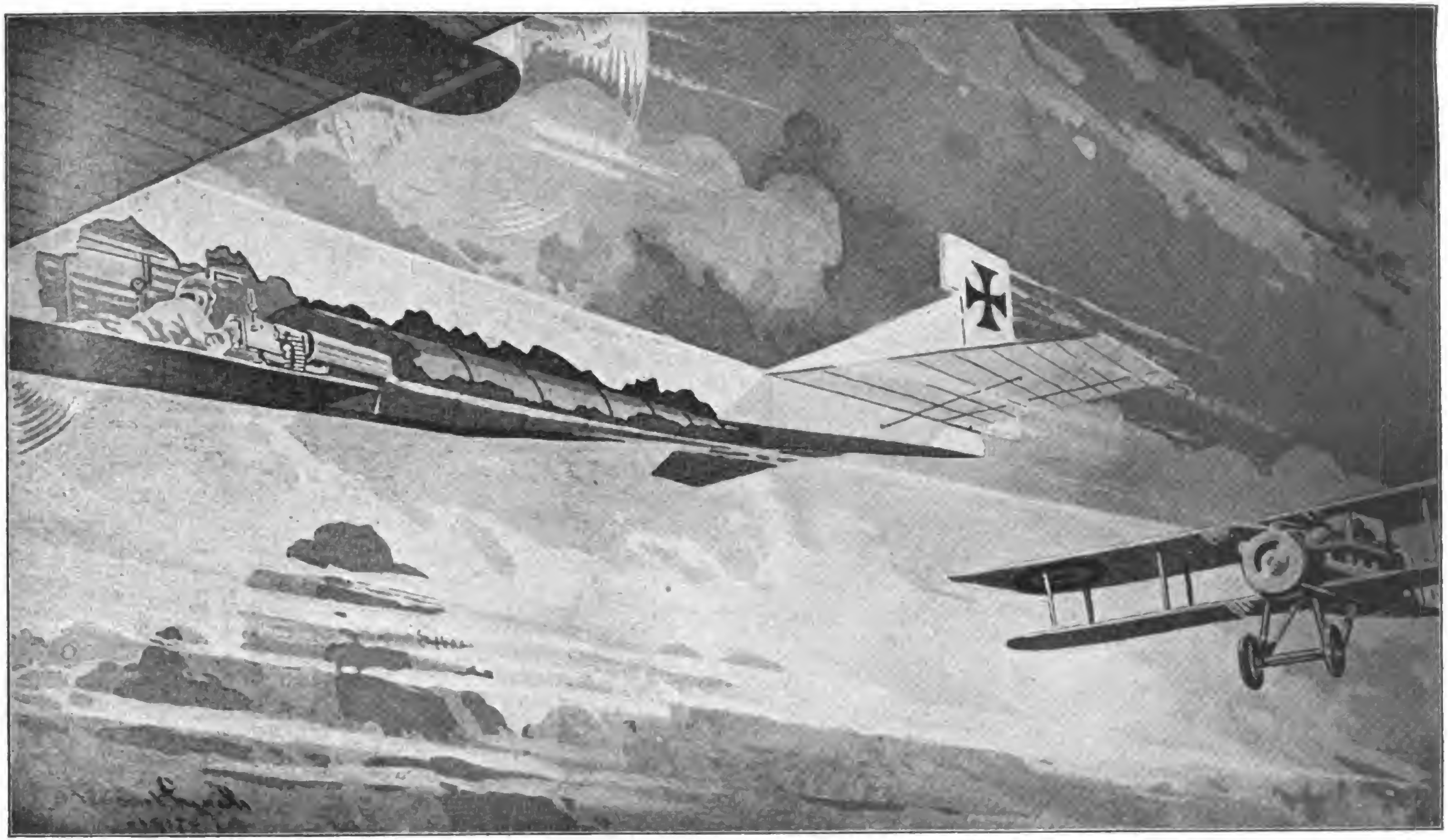
MACHINE GUNS THAT FIRE THROUGH THE PROPELLER SWEEP

Then it began to dawn on every one that the correct place for the machine gun was in front, rigidly mounted so as to fire in a direct line with the direction of flight. To aim such a gun it might be necessary to aim the entire machine, but that was a simple matter with a single-seater plane, such as would have to be used in order to attain high speed and high rate of climb. Soon the demands of speed and climb made the single-seater tractor biplane the standard combat machine of both sides, although a few single-seater tractor monoplanes were used.

The French were the first to solve the problem of mounting the machine gun in front without interfering with the propeller. This they did with their Morane-Saulnier monoplane scout, merely by placing deflector blades of steel on those parts of the propeller which came in line with the fire of the machine gun. Garros was the first to fire a fixed gun through the sweep of a propeller. The gun was worked at its normal speed, and the number of rounds which struck the armored propeller and which were consequently wasted was estimated at less than ten per cent. But the main trouble was that the speed of the

The "Spad" Airplane

Here is shown the complete body and the profile of one of the French planes.

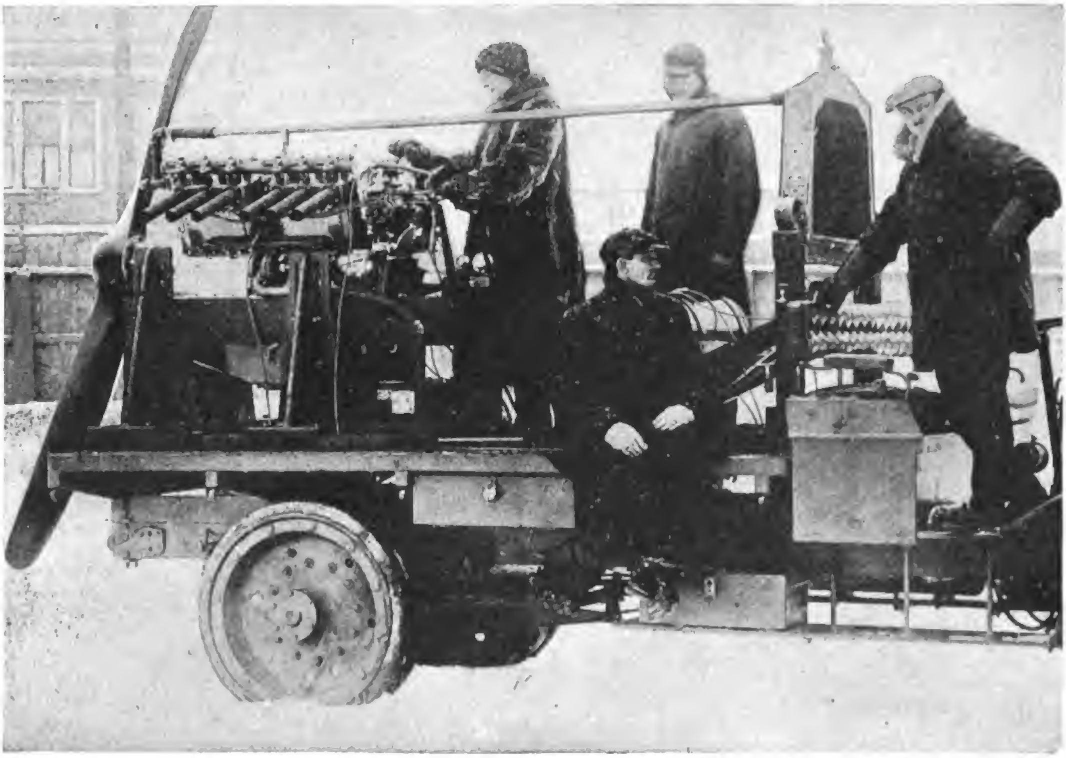


Machine-Gun Alley in the Tail of an Aeroplane

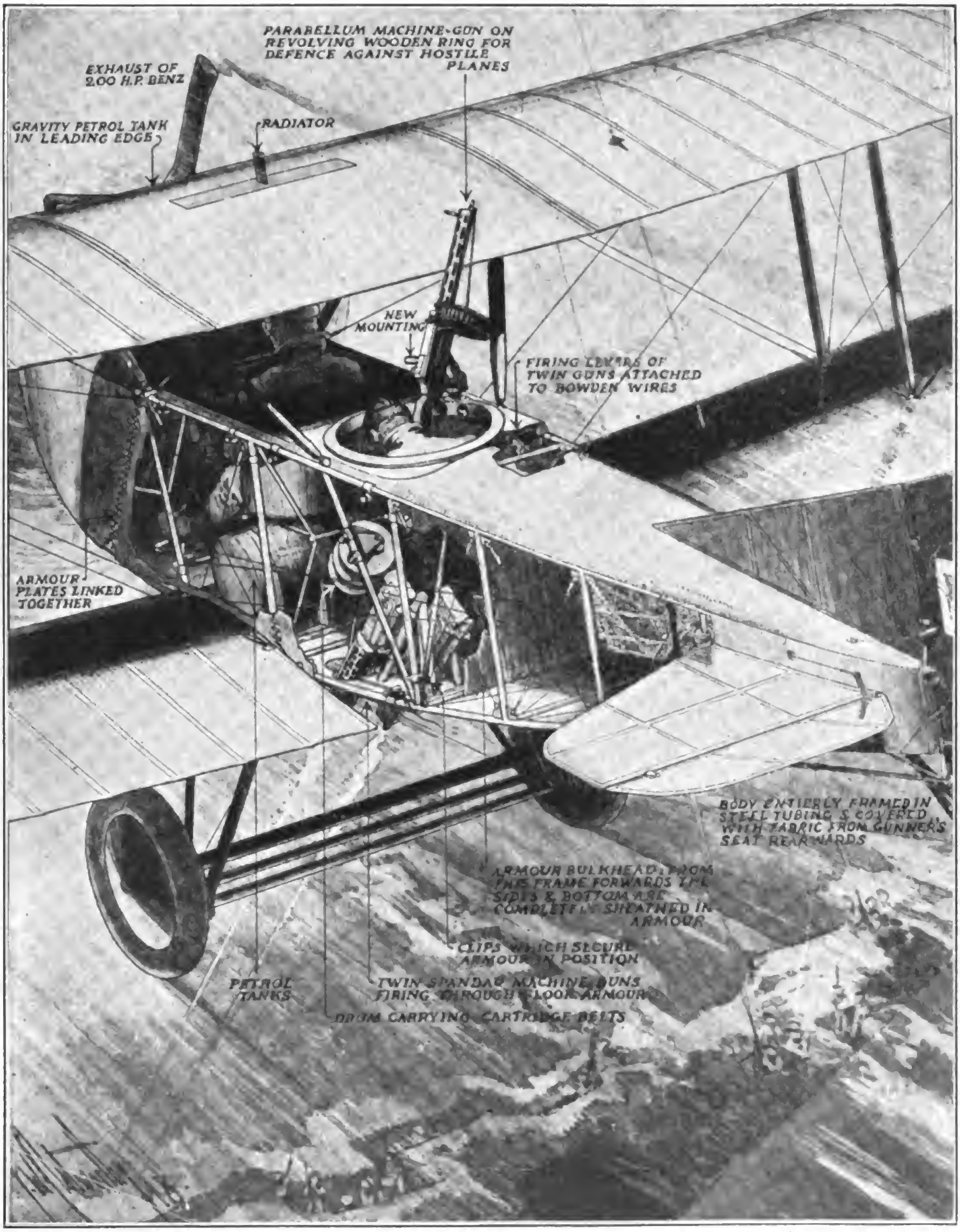
THE SEE-SAW OF AERIAL WARFARE

As for the Allies, they answered the German Albatross chaser with the Spad, a biplane equipped with a powerful engine and armed with a Maxim machine gun rigidly mounted on the engine hood and firing through the propeller sweep by means of a synchronizer. The Spad single-seater made a speed quite equal to that of the Albatross, and being of lighter weight was more responsive to its controls. Indeed, all the way through aerial fighting the German machines were characterized by a heavy build and a powerful engine, whereas the Allied machines were lightly built and lightly powered. Thus when the Allies were using 50-horsepower engines, the Germans were using 100; and when the Allies went to 100-horsepower engines, the Germans were up to 180; and when the Allies got up to 200, the Germans were up to 300. The German practice was to build a plane as substantially and as fully equipped as was found necessary, and then put in any engine that might be necessary to get the desired climbing rate and speed.

The result of these two schools of airplane design was that the German machines were perhaps more sturdy and in a fight were able to dive much faster because of their greater weight. In fact, diving was one of the main stocks in trade of the German aviators, because they knew that they could always get away from an Allied airman by diving. On the other hand, the Allied machines were more maneuverable and usually a trifle faster. Spads and Nieuports were constantly improved in speed and climbing abilities by clipping the wings. Reducing the wing surface of an airplane makes for greater speed but less carrying capacity, and the reduced wing surface makes the machine a poor glider, which means that the pilot faces some danger if the engine fails and he must glide to earth. The Allies also made use of Sopwith single-seaters of the biplane and triplane designs, SE-5 single-seaters, DeHaviland single-seaters, and other types. Both German and Allied chaser or



Testing the First Liberty Motor



Courtesy of Scientific American.

A German Armored Airplane

Showing the details of construction.

combat planes alike were more or less standardized at the end of the war. The representative plane of this type was a biplane or triplane, equipped with two machine guns firing through the sweep of the propeller, and provided with a powerful engine of several hundred horsepower.

TWO-SEATERS—THE GENERAL UTILITY PLANES

So far we have only dealt with the more common types of scout, chaser, or combat planes, the duty of which is to engage the enemy and either put him to flight or destroy him. As aerial warfare developed the armies required other types of machines for carrying out the routine work of reconnaissance, artillery regulation, photographic work, and daytime bombing. In the early days one type of machine was used, but as soon as the fast combat planes appeared, it was found that the two-seaters were hardly a match for the faster single-seaters. The single-seaters, on the other hand, could not carry the necessary equipment and personnel for the routine work, hence various types of machines had to be adopted for the various tasks.

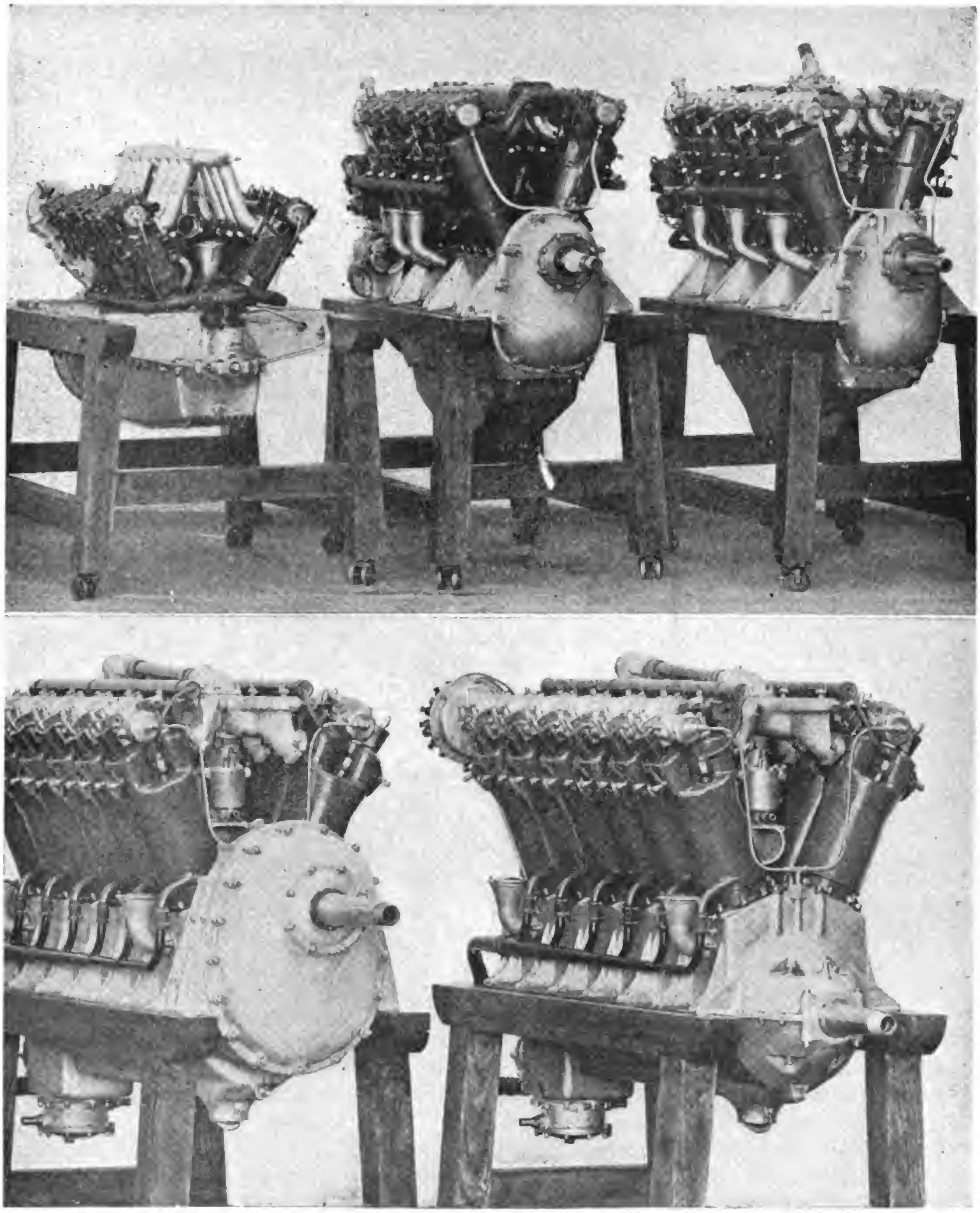
The war was not very old before combat planes were used for attacking enemy machines and defending one's own machine against attackers, while heavier machines carrying two or three passengers were employed for the regular routine of aerial activities. The armament of the two- and three-seater planes consists of one or two fixed guns firing through the propeller sweep, and an adjustable gun or even two guns mounted on an adjustable arrangement in the rear cockpit. The pilot aims the front machine guns by aiming the whole machine, while the rear observer or gunner aims the adjustable machine gun or guns no matter in which direction the plane is heading. Against the fast single-seaters, however, the larger machines can do little but fight a defensive fight. Generally such planes are escorted by single-seaters, at least over the enemy lines where enemy machines are thickest. On long raids the two- and three-seaters are left to their own resources once they have been escorted some distance back of the enemy lines.

Something has already been said about "dead angles" or "blind spots," with relation to machine-gun fire aboard airplanes, and it is interesting to note in this connection that the latest types of bombing planes have absolutely no dead angle. Until the appearance of these machines during the last year of the conflict, even the best two-seater machines had a small blind spot or dead angle just back of and under the tail. Obviously, the gunner at the rear of an observation machine could not shoot at an enemy seeking shelter beneath or in line with his tail for fear of shooting off the elevator and rudder. So it had become part of the technique of aerial fighting for an airman to try for a position under the opponent's tail, so that he could pour a hot fire into the opponent while enjoying absolute immunity from return fire. This was known as "sitting on the enemy's tail." In more recent types of bombarding planes and two-seaters, however, a chute or tunnel with an open bottom was provided so that a gun could be brought to bear on an enemy seeking shelter in line with the tail. In the largest Handley-Page four-engined bombing planes, the British had a cockpit at the very tip end of the tail, so as to shoot down any opponent attempting to find a blind spot.

AIRPLANES WHICH CARRIED TONS OF BOMBS

The Gotha biplane, having a wing spread of seventy-eight feet, and equipped with two Mercedes engines aggregating 520 horsepower, represented the latest German ideals in a bombing plane, but it was surpassed by the Handley-Page and the Caproni triplane, of the British and Italians, respectively. The Germans had a larger type of four-engined Gotha, with a wing spread of over 120 feet. This plane was used to some extent in the closing days of the war for long-distance bombing; in fact, at least one machine of this type was shot down in France.

The Gotha of the type which was used in large numbers for bombing London carried a crew of four men and a ton and a half of bombs. It carried sufficient fuel for a ten-hour flight at an average speed of ninety-five miles an hour and could climb 10,000 feet in twenty-five minutes. The later type of Gotha was equipped with four engines totaling well over a thousand horsepower and carrying perhaps three tons of bombs. The latest Hand-



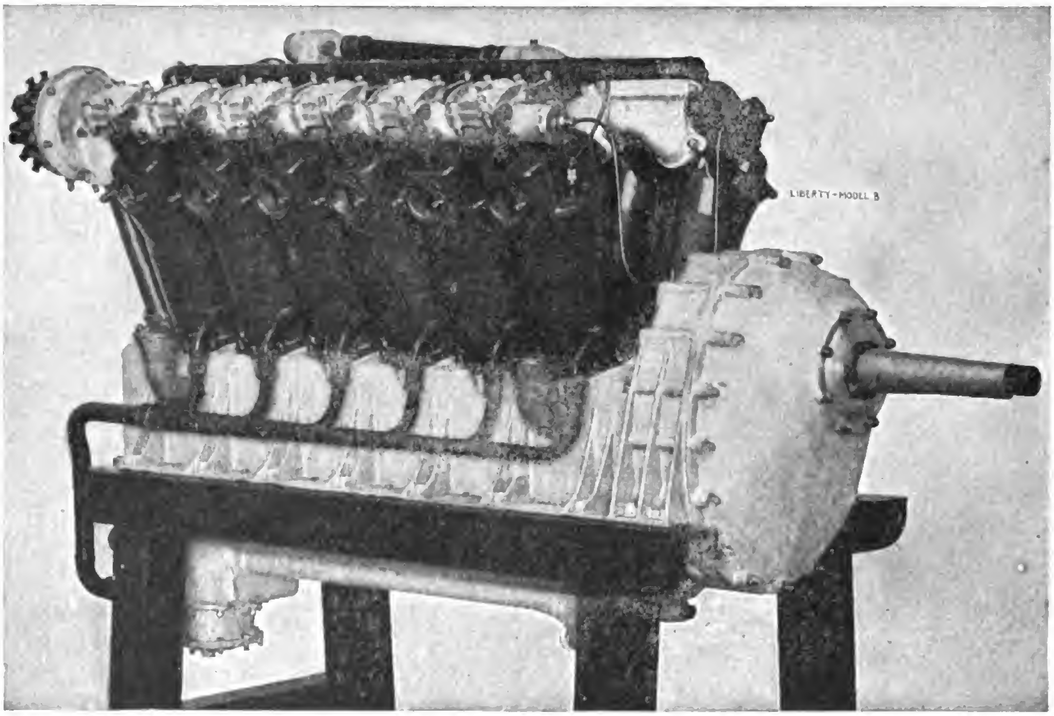
Evolution of the Liberty Motor

The Liberty Motor, and all the aero motors, differ remarkably little in their design from an ordinary automobile engine, except in their astonishing lightness. It was the exquisite balance of parts and weights and the choice of materials that gave them their amazing durability and power.

ley-Page four-engined plane, with something like 1,300 horsepower, was built to bomb Berlin, but the armistice was signed before the first bombing expedition could be carried out. The Caproni triplanes of the Italians were used in bombing Austrian cities and naval establishments.

In the development of machines for aerial warfare, several significant points can be clearly traced. The early machines were for the most part equipped with rotary engines of low power, there being at that time comparatively few reliable stationary engines. The rotary engine, it is well to explain here, is one in which the shaft is stationary while the cylinders rotate about the shaft, the propeller being fastened to the cylinders. The stationary engine, like the automobile engine, is one in which the cylinders are stationary and the crank shaft revolves. The cylinders may be upright and in one row, in two rows and forming an angle in what is known as the V-type, arranged radially to make what is known as the radial type, or arranged to oppose each other, in what is known as the opposed cylinder design.

From the first the need for higher and higher engine power was patent; the original 50-horsepower engines were rapidly displaced by those of 80, 100, and 120 horsepower, in the struggle between the rival air forces. Some one said some years ago that even a kitchen table could be made to fly if equipped with an engine of sufficient power, and in the war that saying was lived up to. The engine was designed for the airplane, rather than the airplane for the engine as in pre-war days.



The Liberty Motor
(The Completed Design)

BRUTE FORCE IN AERONAUTICAL ENGINEERING

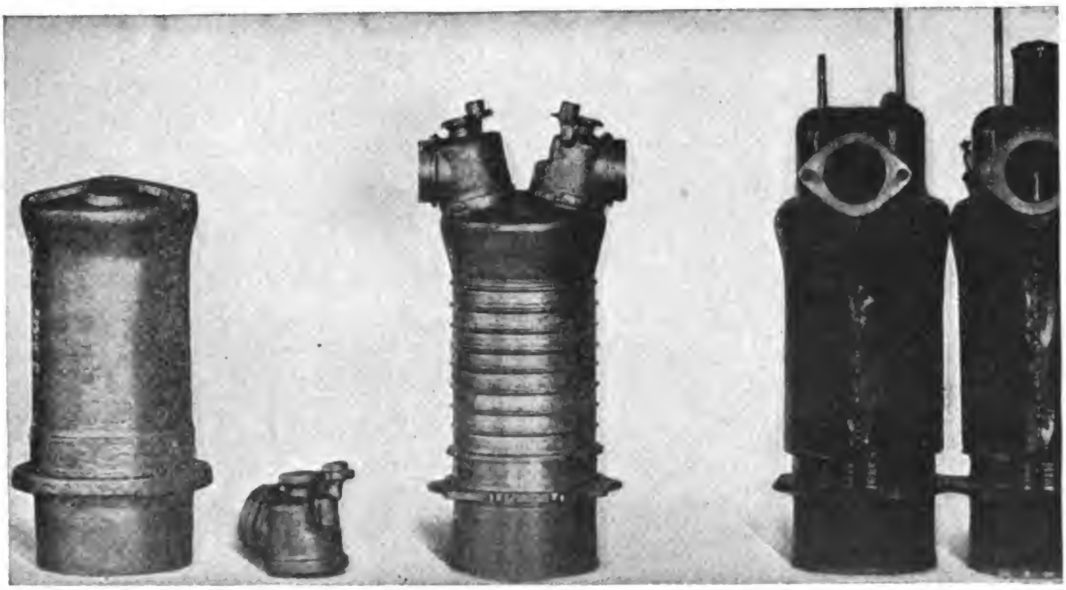
Shaving off every superfluous pound of weight was found a dangerous and difficult way of obtaining the necessary high speed and rapid climbing ability, while augmenting the engine power was a sure and safe means to that end. So instead of reducing the factor of safety, the designers employed brute force,

and, after the abandonment of the rotary engine, engine power jumped from 120 to 160 and then to 200 and even 300 horsepower.

The development of airplane engines has been remarkable. With the replacing of the rotary type by the stationary type, important changes have taken place, mainly in the direction of making the airplane power plant more and more like the automobile engine. Previous to the war if a plane was provided with one horsepower for every twenty pounds of weight it was considered suitable for fighting purposes. To-day a machine of that category can only be used for instruction purposes at a primary training field. To attempt to fight in such a machine would be to attempt suicide, because it would be impossible to make sufficient speed or to climb sufficiently fast. Toward the end of the war the single-seaters averaged eight to ten pounds per horsepower, and in some planes still in the experimental stage the proportion was even lower.

Much of the aerial fighting took place at 10,000, 15,000, and even 20,000 feet, and because of the rarefied air the engine had to be of high power to compensate for the inevitable loss of power at high altitudes. For this reason some of the scouts making 125 to 150 miles an hour were equipped with an engine developing 300 horsepower on the ground. Obviously, such an engine was generally throttled down at low altitudes, and gradually opened up as the higher regions were attained.

It remained for the United States to develop a unique aeronautical engine which is "manufactured" instead of "built," as are all other engines with few exceptions. Heretofore the practice had been to make each part of an aeronautical engine more or less by hand, and then assemble these parts into a single engine. Such methods, of course, are slow, expensive, and rather discouraging when thousands of engines are wanted in a short space of time.



The Liberty Motor Cylinders

The Liberty engine, as we named this wonderful power plant, represents the best practice in the leading engines of our associates in the war and ourselves. But what is of greater significance is its manufacture. It has been so designed that with the crankshafts made in Detroit, the cylinders in Pittsburgh, the pistons in Boston, the ignition system in Dayton, and the bolts in San Francisco, for instance, the engines can be assembled in France. These cities and the place of assembly are imaginary ones, but they go to show what can be done with the Liberty motor by way of turning out thousands of power plants for our air fleet. Furthermore, with an abso-

lute standardization of parts it has been made possible for our mechanics to make repairs quickly and satisfactorily with spare parts, and to make good engines from parts of engines salvaged from the battlefields. Obviously, these undertakings have been absolutely impossible with the engines used by Great Britain, France, Italy, and Germany, with their various types of engines, each of which is usually made by hand with every part carefully filed and fitted in place in the assembly.

Of the famous engines of the war, aside from our Liberty, which, by the way, was made in the twelve-cylinder 400-horsepower model and therefore unsuited to the requirements of single-seaters, the Hispano-Suiza, Curtiss, Kirkham, Lorraine-Dietrich, Rolls-Royce, and Salmson were perhaps the best known toward the end of the struggle, on the Allied side, while the Germans were using their Mercedes, Benz, and Maybach engines.

THE LITTLE THINGS THAT COUNT

The cumulative effect of small details has a considerable effect upon the general efficacy and fighting ability of an air fleet. The most effective policy would appear to be to devote but a minimum of attention to the non-essentials of appearance and finish; and some of the most efficient planes were among the roughest looking. On the other hand, the design should be a homogeneous one, rather than a patchwork of afterthoughts, and the lines of the fuselage or body should be such as to minimize the air resistance. To this end the elimination of luxuries and the proper disposition of the necessary attachments also appear vital. Another important feature of correct design is in avoiding to place the propeller flat against a great radiator, as is only too often the case, and in so sloping the fuselage as to give the slip from the inner portion of the propeller blades a fair lead along the body, rather than throwing them violently outward.

A most desirable airplane construction is the use of ply-wood for fuselage covering. These fuselages are built entirely of layers of thin wood cemented in strips on to one another and built up on a mold the shape of the fuselage. While this construction is necessarily more expensive and time-consuming than the usual procedure of building a framework of wood and covering it with fabric, it more than pays for the extra effort by the strength attained in the finished product. Fabric-covered fuselages are specially vulnerable to bullets: the fabric tears readily; a single bullet in a longitudinal member or longeron may collapse the entire fuselage; a clandestinely cracked longeron may cost the pilot his life the first time he attempts a stunt. On the other hand, the ply-wood construction may be converted into a veritable sieve and still hold together; and it can be readily repaired by the application of fabric patches. It is simply the right fuselage construction.

Pre-war machines were frail, to be sure. They were intended only as straight fliers; they were fair-weather machines; they were not intended for the stunt flying such as was common in the aerial battles of the World War.

With the war came the fast fighting planes, which, aside from their high speed and climbing power, must be as agile as the circus acrobat. In air duels the aviators execute all kinds of maneuvers in attacking and escaping from an opponent. Among the more common are:

The tail slide, in which the aviator by nosing up his machine more and more, finally reaches a point where the planes no longer exert a lifting effect and the propeller, being unable to support the machine, allows it to slide backwards and downwards with increasing velocity. To flatten out again the pilot must operate his elevator and resume an even keel; or he must make a loop. The nose dive is among the most common, and is simply an end-on dive followed by straightening out. A spiral or corkscrew dive is where the aviator allows the machine to dive out of control, and the wings flutter round and round as a narrow strip of paper falling to the ground. The loop-the-loop is merely the turning of the machine in a vertical plane. The pancake is where the engine is throttled down until the machine, no longer possessing the buoyancy which goes only with a fair rate of speed, drops vertically, only to be stopped by opening up the engine and starting the forward movement again.

All these maneuvers are necessary in air

duels, both in securing a position of vantage in attacking the opponent, and in escaping from the enemy when he, in turn, has the whip hand. And with airmen diving and looping and spiraling and sliding, their mounts have been called upon to withstand strains that might well be the despair of the engineer working with steel and concrete, instead of mere wood, linen, tacks and glue.

Sturdy construction, even though it be of wood and linen, excellent design, a powerful engine—all these factors make for great strength in the present airplane. Increasing speed has made for increasing independence from all winds and other weather conditions, just as was predicted years ago.

From 60 to 145 miles an hour; from 10,000 to 20,000 feet altitude; from rotary engines of fifty horsepower to stationary engines of 300 horsepower; from hit-and-miss designs to standardized construction; from one type of machine for all kinds of military service to special types for each class of work—these and numerous other achievements mark the development of the airplane as a direct result of the World War.

AERIAL SUPREMACY

A "Post-Mortem" into the Burning Question of Who Controlled the Sky

WHETHER the Allies or Germany held aerial supremacy during the war has long been a fruitful topic of controversy. This much is known—"Fritz" figuratively and officially gave up the aerial ghost on August 17, 1918; for his swan-song appeared in several official documents captured or discovered about armistice time.

THE BIG "HUN" DRIVE

The Huns, it appears, concentrated their final aerial efforts on the big offensive that commenced in March, 1918, and their strength in the air probably reached its peak at about that time. Activity curves, maintained by the British, displayed symptoms of a decided downhill tendency in April, 1918, and by the following month these curves began to take on the appearance of a succession of saw-edges—each successive tooth representing a spell of good and bad weather.

Apparently the Germans found themselves unable to make good, during active conditions, the replacement of personnel and machines destroyed, and bad weather periods came as much-welcomed respites and were utilized to bring the air units back to fighting trim. Thus each tooth on the curve charts had a peak of its own, representing the tail-end of a replacement period.

Documents captured by the French in July and August gave first evidence of the approaching crisis in German aviation affairs. The Huns attributed this crisis to the heavy losses of the big offensive and also to the unsatisfactory performances of the Pfalz D-III machines and the Fokker triplanes and of one or two other types that were ageing (such as the Albatross D-III and the D-V) which necessitated the development of newer types.

The situation rapidly grew worse as the Allied pressure increased, and, despite the frenzied announcements of the German air officials that the Friedrichshafen and other factories were to be enlarged immediately, and that new materials were to be acquired from Russia and Rumania, late in August the German command apparently saw no reason in keeping secret the fact that the inevitable had come, writes Captain Roscoe Fawcett in the *U. S. Air Service*.

Nobody who has seen the Hun in his lair has come away with any love for him; yet it must be admitted that aerially the Germans were at no time in total eclipse, and, over a long stretch of the four and one-third years of war, maintained an actual aerial supremacy over the combined flying forces of England, France and Belgium.

When the war ended, France had something like 102 or 103 squadrons in the zone

of operations; England between 70 and 80, including four on the Italian front; Belgium five, one of which was a crack squadron; and the United States 40 or thereabouts, with the prospects for an effective aerial force of four times that number of units in operation early in 1919.

Not all the 40 American squadrons at the front were operating intensively or at full strength on November 11th, but a summarization of the effective Allied strength in the air on that date probably would have shown a grand total of approximately 215 or 220 service squadrons. As against this Allied aggregate the Germans were credited with 319 identified units. A great many of these, of course, were flights operating as separate units —not squadrons. Probably the grand total of Hun machines in operation at the front did not exceed 3,500 airplanes.

But the same condition prevailed in the French service. French squadrons, while squadrons in name, were "skeletonized" to a marked extent. Some of the so-called French squadrons could boast of no more than 6 or 7 effective machines. The French flyers, for the most part, were enlisted non-coms, with a sprinkling of officers per squadron. Nor was there the discipline that existed in the British Air Force. The best French pursuit machines were the Spad and the Nieuport; the most effective bomber the two-seated Breguet, and the best corps machine the Salmson two-seater.

© French Pictorial Service.

A German Night Bomber

This is one of the Friedrichshafen planes which was brought down by an Allied aviator.

A STUDY OF "BEFORE" AND "AFTER"

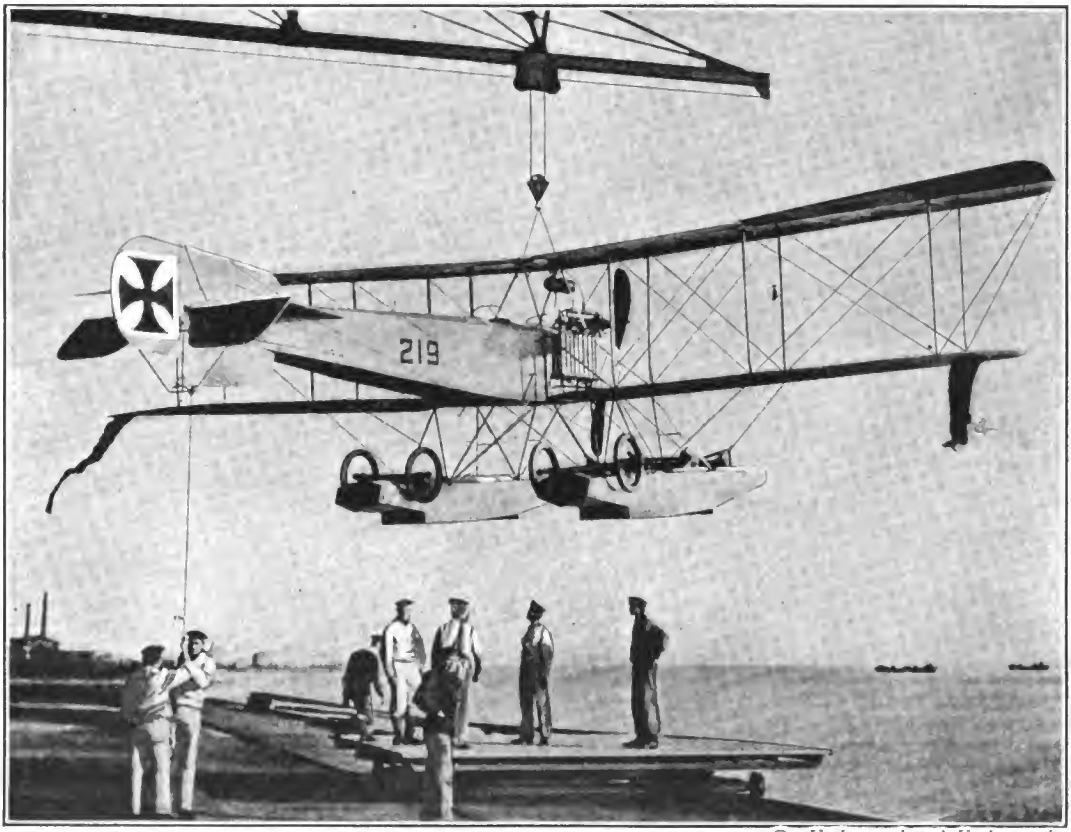
The armistice terms provided for the surrender of a fleet of German airplanes the strength of about 120 squadrons; when the war began the British were able to put into the field only four squadrons. But, by the time of the cessation of hostilities the British had built up a splendid flying service and had founded an organization for the wielding of the third arm as a thing apart from land or sea power. In other words the British had divorced the air from the control of the Army and Navy and combined all aerial activities under one branch—the Royal Air Force.

Undoubtedly the British could have placed as many squadrons at the front as the French; but the British early in the game decided it would be impossible to maintain more than 70 or 80 squadrons at top efficiency and thus the concentration on the fewer number. This policy, too, was much simpler for the British than it would have been for the French because of the difference in the front-line mileage held by the two armies. At any rate

once a British squadron flew across the Channel to an already prepared airdrome behind the British trenches, it was ready for rough and tumble tactics and usually was kept ready.

The British evolved some good engines and some really excellent airplanes. Of these the Bristol Fighter, a two-seater powered by a 260 Rolls-Royce engine, enjoyed remarkable popularity when brought out late in 1917. The Bristol had a speed range from 60 to 120 miles per hour and a ceiling of 20,000 feet. This machine was ultilized in conjunction with scouts in a most striking campaign against German airdromes during 1918.

Forty or 50 Bristols would be sent over at 11 a. m. to shoot up certain previously designed Hun hangars, with two squadrons or scouts hovering at 10,000 feet to act as protectors. As may readily be imagined half a hundred machines flying low over an airdrome and firing lead through two Vickers guns per machine spread wide wreck and ruin. On several occasions more intrepid pilots actually landed on the Hun airdromes and proceeded to add to the demoralization of the enemy. Frequently these armadas would return in the afternoon to spread more consternation amongst those trying to repair the damage.



A German Airplane at Home on Shore or Afloat

The biplane shown in this view is an interesting instance of the aviation novelties which the Germans introduced from time to time. This machine is obviously intended for combined land and water service, being in this instance ready for use as a seaplane.

BRITISH MACHINES THAT GAVE BRITAIN SUPREMACY

The British employed five distinct types of planes: artillery observation—two-seater machines fitted with wireless for work at about

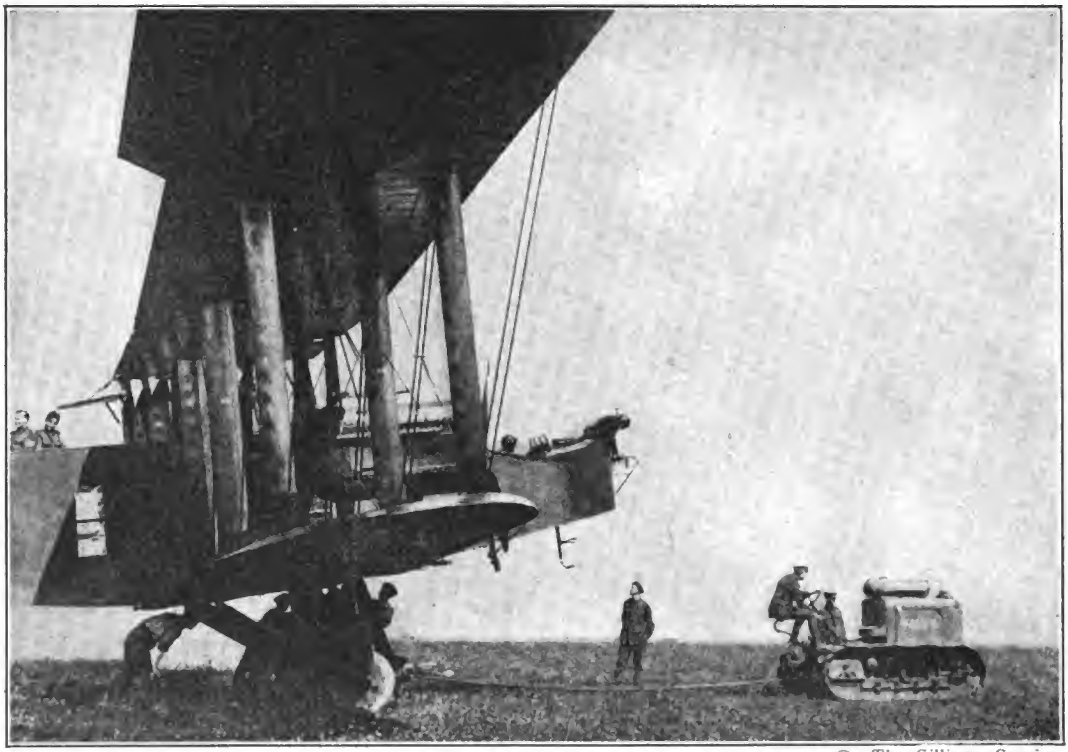
6,000 feet; patrols—a lighter, faster two-seater, working between 10,000 feet and 12,000 feet; scouts—single-seater biplanes of great climbing ability and speed for anything up to 20,000 feet; and the well-known "day" and "night" bombing machines such as the de-Havilands and the Handley-Pages.

The last creation of the Handley-Page factory was a super-Handley, with a span of 126 feet, as against 100 feet for those flown in this country, and four engines instead of two. Nineteen of these behemothic engines of vengeance were due to start from England on a bombing expedition against Berlin on the day of the signing of the armistice. Two engines on these planes were Rolls-Royces and the other two were Libertys, a striking testimonial to the success of this American creation.

The Sopwith Camel and the S. E. 5, together with the Dolphin, carried the burden of the scout-fighting. Late in the war a wonderful climbing machine, the Snipe, was brought out and gradually would have usurped the places of one or two types then becoming obsolete.

Another surprise the British were nursing for the Hun was a huge bomber, the D. H. 10, not as large as the Handley, but capable of carrying about one ton of bombs and of running away from some types of German scouts. This machine was able to do 115 miles at 10,000 feet, while captured German Fokkers could not be pushed beyond 112 miles. Only three of these D. H. 10's had been produced at the time of the signing of the armistice, it is said, but wholesale production was well under way and one machine already had been permitted to fly across for experimental work in France.

This in itself proves that the plans for production were well matured, for, after the lamentable experience with the first Handley-Page machine, which alighted in a German



The Handley-Page Bombing Plane

The motor tractor, as seen in this illustration, was occasionally used to get this giant machine into position.

© Paul Thompson.

Multiplying a Wood Carver's Hands by Eight

It was generally doubted that the United States could turn out an appreciable number of airplanes in a short time. Yet quantity production methods were applied with remarkable results during the war. Here is an instance: A special machine making four propellers at once, duplicating the lines of the master propeller in the center.

airdrome by mistake while *en route* to the British front, the British never let a new type get beyond London until manufacture was well under way at numerous factories. The capture of the original Handley, by the way, gave the Germans the inspiration for their Gotha bombing giants which later harassed many French and English municipalities.

Considering the condition of the British Air Service in 1914, the evolution of this third arm constituted one of the outstanding feats of the war from the British standpoint.

A QUESTION OF TOO MUCH VARIETY

France entered the war with between 500 and 600 fairly serviceable machines, the chief defect in the French corps being the diversity of types. Men who served in the French flying corps have told me that the checking and recording of spare parts would have daunted the hardened heart of a 5-and-10-cent store bookkeeper. France had a well-trained and numerous personnel, however, and good motors. Between 1909 and 1912 there were more builders of successful airplane engines in France than in any other country.

By no means had the Germans been idle. The late Kaiser's aerial armament, both in numbers and equipment, exceeded the combined forces of England and France. Most of his 600 or 700 airplanes were standardized throughout, each machine equipped with bomb-dropping devices, speed and altitude recorders and cameras. The equipment also included automatic engine-starters 100 per cent more efficient than those of the Allies. The wireless equipment and the system of wireless stations along the coast and frontiers assisted materially to the Hun aerial supremacy in the early stages of the war.

Germany's chief advantage, however, lay in the long experience of her engineers and builders.

Behind the line factories were running full-blast in August, 1914, turning out craft to increase German superiority. German airdromes were placed close to the frontiers in strategic positions. German flying fields during the first year of war were superior, it is said, to some of the Allies' flying fields two years later.

Night flying was a part of the instructional course of every pilot. Light-houses dotted the country. Huge letters of glass, illuminated from beneath, were set on the landing fields, and pilots were supplied with information as to clouds, weather predictions and other useful knowledge by means of rings and arrows and other warning signs. From the very beginning the Hun made all his airplane tests of a military nature and curiously, the majority of the pre-war reliability tests carried out by army pilots seemed to involve a great deal of flying over the French and Belgian frontiers.

Germany admitted the existence of no fewer than 21 illuminated aircraft stations. That at Weimar consisted of a revolving electric flash, located 80 feet above the airdrome, giving 27,000,000 candlepower.

Engine factories such as the Mercedes, Benz and Maybach were standardizing their products while the British and French were experimenting. It is a fact that the entire output of the Benz factory was commandeered for war airplanes one year before the declaration of war. As a subtle indictment of the late Kaiser of having forced the war, it is cited in England that, after having held out of the world's famous automobile races for years, German manufacturers again took to the road just before the start of hostilities.

The Mercedes team entered the Grand Prix in 1914 and easily demonstrated a marked superiority. Hundreds of Hun aircraft were fitted with this Grand Prix type of car engine.

PRE-WAR RECORDS WITH A SINISTER MEANING

Before the war some excellent biplanes had been built in Germany by Herr Rumpler, who produced the Rumpler Taube. Record after record fell before this machine. In June, 1914, Herr Linnekogel on a Taube monoplane established an altitude record of 21,600 feet.

Herr Bassler startled the world a little later by a continuous flight of 18 hours and 10 minutes on a Rumpler biplane, and, as showing that some others besides Herr Rumpler knew considerable about flying in pre-war days, another German in that same momentous year flew an Albatross biplane for 24 hours and 12 minutes without landing. That flight would have taken the pilot across the Atlantic with three or four hours to spare.

In the matter of seaplanes there was not much to choose between the rival powers, as very little progress had been made in the development of this craft prior to the war. England and France had a few seaplanes, and Germany, it will be recalled, had bought the Sopwith seaplane and also was developing the Wright seaplane.

The French and British seaplanes did good work from the start, levying a heavy toll on Zeppelins and doing good "spotting" for the battleship guns. It was a seaplane that gave Admiral Beatty of Jutland Battle fame the first news that the German Grand Fleet was out.

Aerial supremacy is not a very tangible element because of the fact that heavy concentrations can be made at any point in a remarkably short space of time, and, of course, the side with the heaviest concentration holds the supremacy until equilibrium has been restored. But, with all its fickleness and intangibility, aerial supremacy undoubtedly lay with the Germans during the early stages of the war.

During the first two years up to the first battle of the Somme in 1916 the Germans harassed the sorely-tried Allies in the air. Fortunately for the British and for the world as large the Hun had the Russian front to protect and many of Germany's finest Albatross and Rumpler biplanes were sent there, while Taube-type monoplanes were concentrated on the Western front in an attempt to overwhelm the French.

With the début of the combat patrol in 1917 and the appearance of new type English planes the Allies began to make progress. But, the Huns countered late in 1917 with the D-VII Albatross and a new Rumpler and at no time were in total eclipse until past midsummer of 1918, when every resource had been staked on the great German attempt to break through the British lines to the Channel ports.

The Allies did more flying late in the war, and for this reason undoubtedly had the best pilots, but the Germans planned more wisely in their way, handled their squadrons in the field with more astuteness, and, considering every angle in retrospect, gave the Allies a jolt that should serve as a perpetual warning against future butterfingered brainworks so far as the development of air service is concerned.

The Famous Leoning Monoplane

An American machine powered by a 300 H. P. Hispana-Suiza motor.

THE VOGUE OF THE STREAM LINE

A whole corps of specialists were engaged in all the warring nations in constantly re-designing the airplane so that it should encounter a minimum of resistance from the air; and the resulting stream-lined fuselage is familiar enough. But not everybody would suppose that the wires and struts that are seen on a plane in such numbers also present sufficient surface to the wind for the resistance to their passage to be a factor of importance. The latest planes, on examination, will be found to have no round wires or braces—these members as well as the fuselage are stream-lined to reduce the expenditure of power.

SOME ODDITIES OF AIR FIGHTING

Machine Guns that Fire through the Sweep of the Propeller, Guns that Shoot Photographs instead of Lead, and Special Bullets of Warring Airmen

IT seems a mechanical anomaly that many of the battleplanes flying over the fighting forces of Europe should have been equipped with machine guns that fire through the path of the revolving propeller. Yet this condition has been brought about by the development of the fast and highly-flexible battleplanes, such as the single-seater Spad, Fokker, Sopwith, and other famous airplanes.

High speed and flexibility of control are the two main requisites of a battleplane, for the victory in an aerial duel rests with the aviator having the fastest and most flexible mount, the skill of the adversaries being equal. Hence in the development of the battleplane it was found necessary to eliminate the gunner or *tireur* whose duty was to fire the machine gun while the pilot devoted his attention to the navigation problems, thus bringing into being the single-seater fighting machine whose pilot, aside from his usual responsibilities, has to shoulder the additional duties of gunner and observer.

In the present-day single-seater battleplane the machine gun is usually placed in front of the pilot, on the engine cowl. Most machines are equipped with twin guns, which may be fired together or independently, and the fire of which is arranged to cross at some 100 yards or so in front of the machine. Since the pilot is unable to remove his hands from the control levers for any considerable length of time, the sighting of the guns is accomplished by aligning the entire airplane with the target and then opening fire at the propitious moment. The machine guns, of course, are rigidly mounted on the airplane.

BREAKING UP A STREAM OF MACHINE-GUN BULLETS

In certain of the early French battleplanes the gun was fired continuously through the path of the revolving propeller blades, no attempt being made to select such times for the firing as when the blades are not in the path of fire. The portion of each propeller blade coming in direct line with the muzzle of the machine gun is sufficiently armored so that the bullets that strike are deflected without causing any damage, and it is estimated that under no circumstance does the wastage of fire exceed thirty per cent. But the greatest handicap with this arrangement was found to be the serious loss of speed. The propeller was retarded by the bullets which struck it, and the machine's speed was reduced by some eight to ten miles an hour.

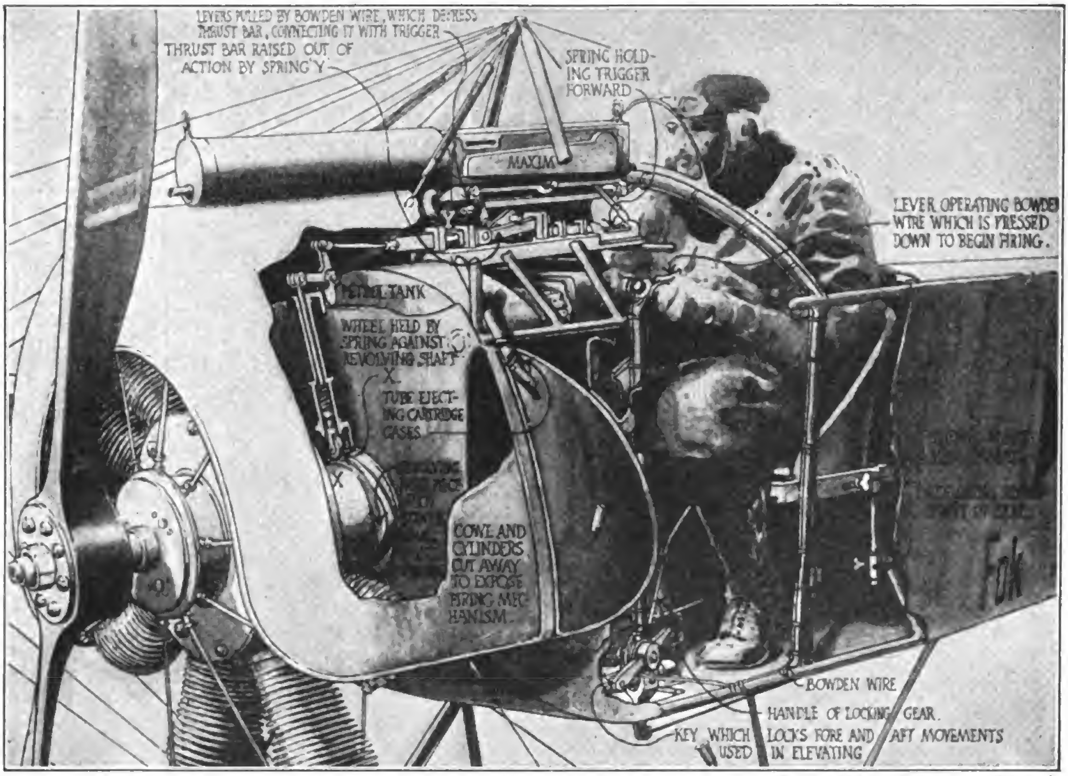
In designing their premier fighting machine of 1915, the Fokker, the Germans endeavored to improve on the French machines by eliminating the wastage of ammunition and the loss of speed. The wastage of ammunition ordinarily would mean little, for in a great war a few million rounds one way or the other is a small matter; but it was the fact that an airplane can only carry a limited quantity of ammunition that prompted the Germans to make every shot count, if possible. The result was a machine gun that fired through the propeller sweep only at such times as the blades were out of the way.

This firing mechanism, known as a synchronizer, was subsequently used on all German machines, both of the single-seater and two-seater types, or wherever a propeller was used in front of the forward gunner or pilot. The Allies copied this mechanism rather closely at first, but soon developed a far more effective device which is described further on.

The mechanical synchronizer of the Germans is shown in the accompanying illustration, installed on a Fokker plane of the type widely used in 1915. The control mechanism of this machine, it will be noted, consisted

of a single post fitted with handle bars similar to those of a bicycle, supplemented by a rudder bar operated by the feet of the pilot. The elevation and depression of the horizontal rudder is effected by the backward and forward movement of the steering column, while the lateral stability of the airplane is maintained by the side to side movement of the post by means of the pilot's knees acting eral balance by moving the control post with his knees; but he must continue the flight in the same plane until the elevator is again freed. This procedure permits the airman to use his hands, since they are no longer required on the handle bars.

The machine gun of the Fokker is of the Maxim type and is immovably affixed above the engine cowl and slightly to the right, so



© Underwood and Underwood.

Shooting Bullets Through a Revolving Propeller

This drawing shows how the Germans first introduced a method of shooting a machine-gun through the sweep of a propeller. A simple transmission system from the propeller shaft renders the gun inoperative at the moment either blade is in line with the machine-gun muzzle.

on an adjustable sliding sleeve. The seat is adjusted both horizontally and vertically.

AIMING A GUN BY AIMING AN AIRPLANE

The first move of the Fokker pilot after engaging with an enemy airman is to settle on a certain plane of flight and then lock the elevator control by means of a lever, so that he can then steer to right or left by the action of his feet on the rudder bar and maintain lat- that its line of fire passes through the path of the revolving propeller in front. In sighting his gun the pilot, as previously stated, maneuvers his airplane until the sights register on the target. This task calls for a high degree of skill, for both the firing medium and the target are mobile, while the steering of an airplane is accomplished by relatively slow movements of considerable amplitude.

Instead of the machine gun being fired by pulling the trigger, as in usual practice, the

trigger is operated by a cam and transmission mechanism under the control of the pilot. On the revolving shaft of the rotary engine is a disk carrying a slight bulge at one point whose relation is at right angles to that of either propeller blade. Upon this disk rests a small wheel, which receives the reciprocating movement brought about by the use of the cam member. The reciprocating movement is transmitted by a system of levers and springs terminating in a hinged piece. Normally, when the gun is not firing, this piece is raised so that the reciprocating movement ends with it; but at the moment the pilot is ready to fire the gun he presses a small lever fixed in the center of the steering bar control, which, by means of a bowden wire, causes the hinged piece to be brought down in line with, and to act upon a lever connected directly with, the trigger of the gun.

The action of the firing mechanism is to pull the trigger of the gun once for every revolution of the engine and propeller, at the moment when neither of the two propeller blades is in the line of fire, in spite of the high rate of revolution of the propeller, which normally reaches some 1,200 revolutions per minute or twenty revolutions per second. Since the average machine gun fires anywhere from 400 to 600 rounds per minute, or six to ten per second, the opportunity to fire twenty times each second is ample for the proper functioning of the gun when the engine is turning over at the usual speed.

PROBLEMS IN AERIAL MARKSMANSHIP

One of the greatest difficulties experienced by aerial fighters, when machine guns on airplanes came into general use, was to hit the target aimed at. This may seem, to the uninitiated, like a bald statement of poor marksmanship, but in reality it is not. As a matter of fact to bring down an enemy machine without specially designed sights is nothing more nor less than pure, unadulterated luck.

For instance, imagine two machines passing each other along parallel lines, 100 yards apart, each traveling 100 miles per hour. You are equipped with a machine gun firing 700 shots a minute—eleven each second—the bullet traveling at the rate of 4,960 feet per second. If you took a dead aim at the enemy machine your first bullet would miss its mark by eighteen feet, and the second bullet, coming one-eleventh of a second behind the first one, would miss its mark by forty-five feet.

To offset this, and to make aerial fighting more of a science, ring sights were devised. These sights consist of two rings, a small one, representing the bull's-eye, and a larger one, encircling it, representing the line of flight of the bullet. If aim is taken when the enemy

© International Film Service.

Multiplying the Planes to Multiply the Speed of Airplanes

At the beginning of the war the monoplane was considered the best type for aerial fighting, because of its high speed. But as the war developed the tendency became more and more toward biplanes, and later toward triplanes, such as this exceptionally speedy Curtiss triplane.

machine is crossing the outer circle (the hostile aircraft being 100 yards distant and traveling at the rate of 100 miles per hour) the bullet would reach it as it enters the smaller ring, constituting a direct hit.

But this only compensates for the speed of the enemy machine. You still have to make allowance for the speed of your own machine. This is done by means of the Norman compensating foresight, a bead sight fitted to a swivel, with a wind-vane swinging on one side, which raises and lowers the bead, and revolves on its axis, according to the pressure of the wind in the slip-stream.

The most wonderful of all sights, however, is the Aldis Optical Sight, used for stationary guns when firing through the blades of the propeller. This sight was invented by the two Aldis Brothers, manufacturers of lenses, who, under subsidies from the British government, have brought the making of high grade lenses to a higher point than the German's finest workmanship.

The Aldis sight is virtually a telescope which neither magnifies nor diminishes, and which, unlike an ordinary telescope, can be used with the eye several inches from the end of the tube.

When looking through this tube at a distant object the effect is exactly as though one were looking through a napkin ring—the object appears the same whether it is seen through the tube or outside it—but, apparently suspended in the air, is a ring sight. The peculiarity is that the ring is seen with its center on the spot at which the tube is pointing, no matter where the eye is placed. If the eye is moved sideways the ring appears to move with it through the telescope, so that the direction in which the tube points is always toward the center of the ring.

The tube, when fixed rigidly to a gun, thus constitutes a sight which offers practically no obstruction to the view, and which shows instantly the spot at which the gun is pointing, without the necessity of aligning the eye on a front and back sight. The effect produced on the pilot of seeing an enemy machine flying into this ring suspended in mid-air is quite startling.

One advantage of this sight is that it can be used with both eyes open. One eye sees the object and the circle through the tube, the other eye sees the object direct. The effect, after a little practice, is that the object is seen as clearly as though there were no sight at all.

The tube is about three feet long and about three inches in diameter, and contains five specially constructed and arranged lenses.

© *Underwood and Underwood.*

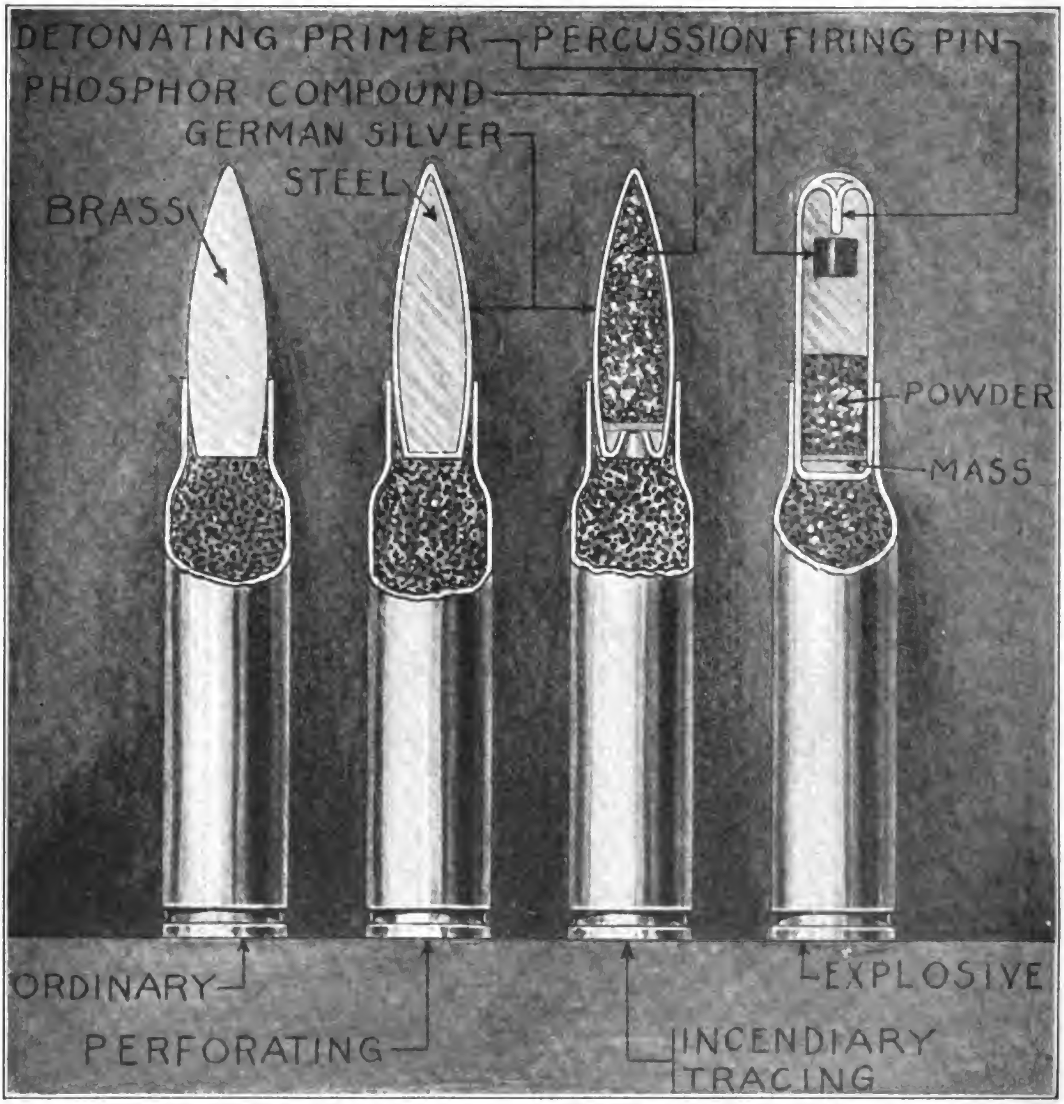
Looks Deadly, and Is So

A French reconnoitering machine with two machine-guns joined together on a turret behind the pilot.

One fact about aerial fighting, however, which has never been mentioned is that, after the first sight has been obtained, the pilot never uses his sight at all. He watches the bullets—literally! That is, he watches the tracer ammunition. One in every three shots is a tracer—a bullet which trails a little path

of smoke; and it is much more interesting to watch the tracers than it is to keep the eye on the sights. Most pilots would like to use *all* tracers if they could, for they kill as readily as the regular bullets. But, unfortunately, tracer ammunition is dirty, and will soon choke the bore of the gun. As it is, a great many pilots load their magazines and belts with every other one a tracer, though it is strictly against the rules. The temptation though is too great to be resisted.

The tracer is made the same as the ordinary bullet, except that in the end is a small quantity of magnesium which ignites. It is not quite accurate, as it is lighter, and drops a little in its flight, but it serves its purpose wonderfully.

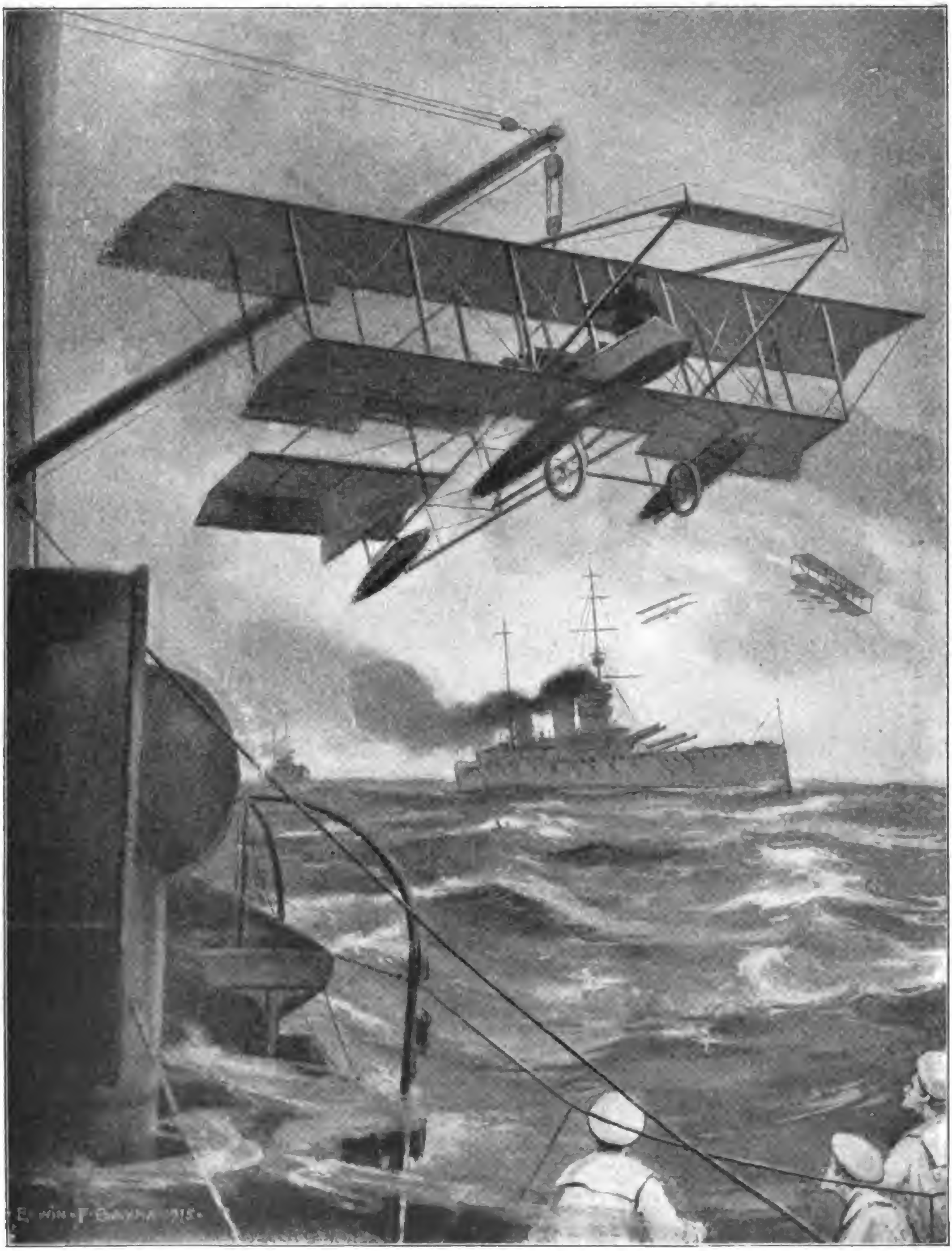


Courtesy of Scientific American.

Four Types of Bullets Employed by Fighting Airmen

In carrying on the war in the air, the fighting airmen employed four kinds of bullets, namely, ordinary, perforating, incendiary-tracer, and explosive, all of which are shown in this drawing.

There is a fortune waiting for the man who



Courtesy of Scientific American.

An Early British Hydro-Aeroplane

Here is one of the early British airplanes, provided with pontoons, being loaded aboard a battleship. In the closing days of the war, the British had huge airplane mother-ships, accommodating dozens of airplanes, which could start and alight on the broad and long deck.

can devise a tracer that will not foul the bore, and which will accordingly permit the aviator, or indeed any machine-gunner operating at short range, to employ it exclusively.

SPECIAL BULLETS OF THE AIR FIGHTERS

With the introduction of the armored or partly armored airplane, it has become necessary to introduce the armor-piercing bullet. In the case of the German bullet for this purpose, it will be noted that the projectile consists of a German silver jacket to take the rifling of the gun barrel, with a core of steel. Obviously, such a bullet has great piercing powers, and it is reported that the German airmen made particular efforts to disable the engine of their opponent with this type of missile.

The gasoline tank being the most vulnerable member of the airplane, especially if it can be set aflame, special incendiary bullets have been developed for the aerial fighters. The German incendiary or tracing bullet is hollow, and contains an incendiary matter of a phosphor base. It leaves in its wake a luminous and smoky train, destined to ignite balloons and gasoline tanks and to permit the gunner to rectify his fire. Even in total darkness, the gunner can follow the trajectory of the incendiary or tracer bullet by means of the bright spark, while in daylight he observes the smoky wake.

Explosive bullets of the type shown are intended for all around purposes. Indeed, they are very much in the nature of a small shell, containing a small plunger forming a percussion firing pin over a detonating primer. It is said that this type of bullet was carried in belts and drums in the proportion of about ten to fifteen per one hundred, in German fighting planes.

The German has been shown up by the late war as an imitator rather than an inventor. His forte lies in taking an idea from some foreign source and squeezing the juice out of it until it gives up an amount of practical utility which its conceiver would never have supposed to lie in it. And by the same token, when any one develops an idea which baffles the German, he has done something of which he may well be proud. The Germans took over and improved the submarine and the machine-gun and a host of other British and French and American inventions; but there was one little invention, which first saw the light during the war, and which Fritzie never was able to use—apparently for no other reason than the very good one that he couldn't figure out how it worked. This was a device, weighing but a few pounds, known to the initiated as the "C. C. Gear." It was this gear which gave to the Allies a goodly portion of their indisputable mastery of the air, and was thus instrumental in bringing the war to a more speedy close.

A GEAR THAT WAS SO SIMPLE THAT IT BAFFLED WOULD-BE IMITATORS

This device is far from being a complicated one. Contrary to the impression which has been allowed to go abroad, and even to some extent to prevail among the Allied airmen themselves, it involves no new principle, no factor of mystery whatever. It contains no intricate mechanism, operating merely by pressing a button or lever. Yet it successfully defied solution by every noted scientist of Germany and Austria for a period of two years during which samples of it were continually falling into Boche hands on captured planes.

The term "gear" as used by pilots of the air signifies a mechanical device by means of which a machine gun may be timed to fire between the fast revolving blades of a propeller. There are more than a few of such devices; we have just described one; but the C. C. gear differs from all the rest in the fact that it is non-mechanical. The tremendous advantage of this will be realized when it is remembered that the terrific speed at which it must operate necessitates the timing of the gear to fire accurately 700 shots a minute through a two- or four-bladed propeller revolving 2,000 times a minute.

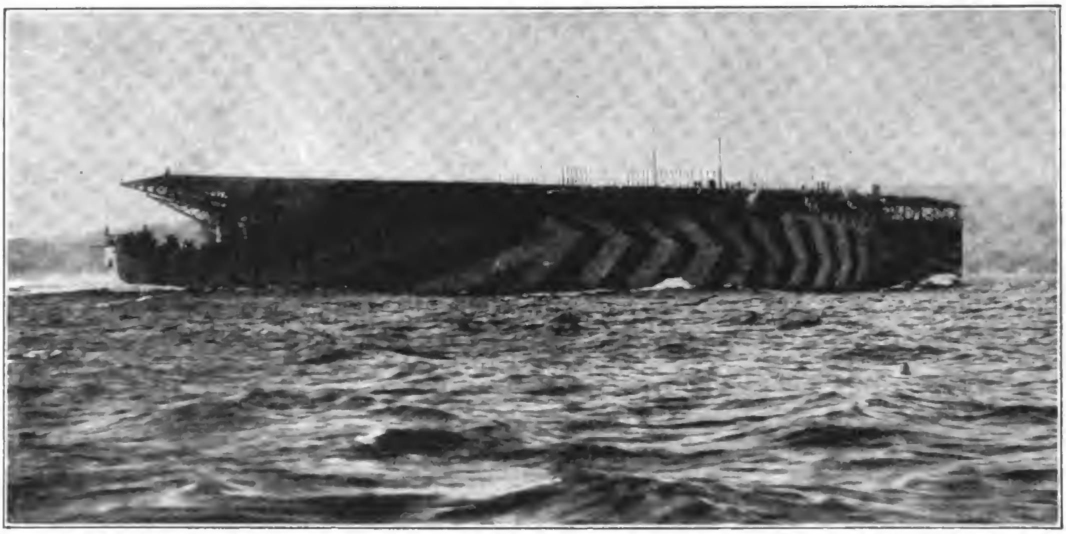
The idea once in hand, numerous mechanical gears were brought out, but all were handicapped by one great drawback which it seemed impossible to overcome. The timing was a delicate operation, and the adjustments necessarily fine. The mechanical gear, constructed of metal parts, could be timed perfectly on the ground, but the intense cold of the higher altitudes caused the metal to con-

tract, and the timing would be thrown out of adjustment. Furthermore, the very active friction of the working parts caused severe wear, and so tended to nullify the accuracy of operation.

The problem came to the attention of M. Constantinesco, a Rumanian by birth, naturalized in England, and he applied to it a principle in which he had just become greatly interested—namely, the transmission of power through a column of fluid. Because he encountered this principle while experimenting with sound waves under water he named it the operate it—for its advantages are so marked that had they been able to unravel the secret, they would surely have used it.

SHOOTING A GUN BY THE PRESSURE OF LIQUID

The apparatus consists essentially of a copper pipe filled with oil, at one end of which is a piston and at the other a push-rod to operate the trigger. The piston is connected with the propeller shaft by gear and cam. At the proper instant in each rotation of the propeller, the hump on the cam drives the piston down upon



Courtesy of Scientific American.

A Camouflaged Airplane Carrier

By means of the long broad deck, airplanes are able to rise from and alight on this boat. The funnels were horizontal and located at the stern in order more successfully to deceive the enemy U-boats.

"sonic" principle. He emphasizes that it is not as though the fluid were a rigid column, and imparted shock in the same way that a sledge imparts the blow of a hammer to a bar upon which it is held by a second workman. There is actually generated, by an impact upon one end of the column, a pressure wave, which traverses the column at the rate of 4,900 feet per second, delivering a blow at the other end, not instantaneously, but after the lapse of the infinitesimal interval called for by this velocity and the length of the tube. It was doubtless their failure to appreciate that the outfit did not constitute a rigid system that kept the Germans from learning how to the end of the oil column, which is under a pressure of 150 pounds. Through this compressed column the shock of the piston blow travels as a pressure wave; and when it reaches the other end it operates the firing mechanism. The rotation of the propeller generates 40 to 60 of these wave impulses per second, with no friction except the very slight amount to be found between the gear and the cam.

It is, of course, not desired that the gun begin firing the moment the pilot takes the air, and continue until he makes his landing and stops his engine. So some means of control must be provided, and this is made possible by the necessity of having the oil column

under pressure before it will transmit an effective blow. A small chamber is provided, connected with the copper pipe, and normally the oil occupies partly this chamber and partly the pipe. When it is desired to set the gun going, the pilot throws a small lever connected with his joy-stick, and this, with the aid of the spring in the reservoir, expels the oil from the reservoir, forces it out into the pipe, and puts it under pressure there. Then things begin to happen in the oil column, and the gun begins to speak.

Courtesy of Scientific American.

An Air Raid Warning

One of the huge sirens which were used in Paris to warn the populace of German air raids.

A GUN WHICH SHOOTS PHOTOGRAPHS INSTEAD OF BULLETS

In casting about for a suitable method of training aviators in aerial marksmanship, it was the British who first introduced the so-called gun camera. This device in its early form was simply a camera patterned after a Lewis gun, with a long lens barrel in place of the usual barrel. The gun camera was then a cumbersome contrivance; its operation did not simulate that of a genuine Lewis gun; it carried plates for 12 exposures only; and each exposure called for a manual operation.

Then the United States entered the war, and among other things the matter of a satisfactory gun camera came up in due course. As a rush job, the British gun camera was not at all bad; but after a while the American camera designers came forth with an idea for making the gun camera a separate device that might be attached to any standard Lewis gun. In that manner, they pointed out, it would be possible for an airman to obtain more realistic training. Again, more realism called for a camera that could make 100 exposures at one loading, and like the machine gun could fire in "bursts" and continue firing automatically as long as the trigger was under pressure.

The gun camera in its perfected form weighs only 13 pounds in all, and has a lens barrel but 8 inches long and 2½ inches in diameter. It is of metal construction throughout. The film magazine is oval shaped. It is fitted with a Lewis gun magazine lock, which serves to fasten the film magazine in place against any ordinary shock.

Soon after the gun camera was introduced arguments arose at the training fields as to which aviator first shot the other, when both showed hits on their film. This necessitated the introduction of some form of time indicator. At present the gun camera in photographing a hit also registers the time on the same image.

It was believed at first the aiming of the gun camera would have to be done mechanically, and one had visions of intricate gears and other mechanism. But the problem of aiming was solved by a system of mirrors.

The gun camera is properly registered with relation to the sights of the machine gun to which it is attached by first sighting the machine gun on a point a definite distance away, and then moving the camera so that the point of the bisecting lines of the "graticule" falls exactly on the point where the gun was sighted. Suitable clamping members then insure the accuracy of aim.

In place of the explosive force of the usual cartridge, something had to be introduced in the gun camera for driving the mechanism. The designers in the present and latest model have made use of a spring, which is wound with a handle similar to that employed in winding phonograph motors. The spring is fastened directly to the shaft that turns the five-inch reel and through to the Geneva cross movement which causes the intermittent action of the shutter and film-shifting mechanism,

each time the gun is fired. The film is standard motion-picture stock, and in the gun camera it travels from a spool in the small end of the magazine, past a light trap where it is exposed and thence to a reel five inches in diameter at the larger end of the magazine, where it is stored until developed. Each gun camera is ordinarily provided with three magazines, which may be loaded in daylight.

The "hits" are recorded on the motion-picture film in such manner as to render easy interpretation of the results. A set of crossed lines serve to indicate the accuracy of aim with relation to the airplane photographed, and a white clock dial indicates the exact time even down to the second. A glass plate called a "graticule" is interposed in the lens barrel at the focal plane of the lens, which means practically in contact with the film. The graticule carries the crossed lines and circle, which are photographed in each image recorded. The developed images serve to indicate whether a given "shot" would have proved vital or not in actual combat.

HOW THE AIRPLANE FLIES

The Navigating Instruments Employed by the Aerial Pilot, as Revealed by American War-Time Developments

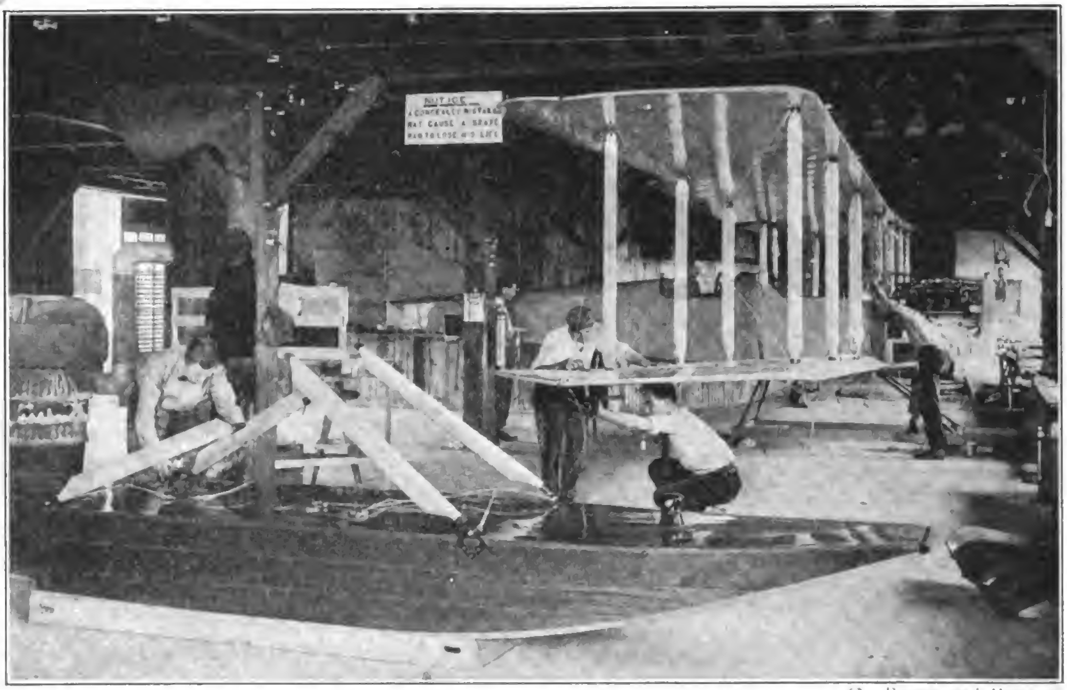
BEFORE an airplane can be put into military service it must be equipped with nine or more delicate aeronautic instruments, some of which are absolutely essential to exact flying, and all of which contribute to the successful operation of a plane. Without them a pilot would lose his location as to height and direction; he would not know his speed through the air, the speed of his propeller, the amount of gasoline in his tank, the temperature of his cooling water, or how his oil was circulating. He could not tell whether he was banking properly on his turns. These comprise the necessary flying instruments, but an aviator could not fly to any great height without another valuable instrument, an oxygen supplying apparatus, nor could he operate his guns, signal headquarters, release his bombs, or "shoot" his cameras without additional mechanisms.

All these instruments must be ready for installation on the airplanes as soon as they are assembled, for no plane is complete without them. In some instances, particularly for the two-seaters and the heavy bombing machines, two and even three instruments of each sort are necessary, totaling sometimes as many as 23, but for ordinary work only about nine of them are needed. The average cost of a set of navigation instruments for a single plane is $350.

For operation of actual combat planes, such as observing, photographing, bombing, and fighting planes, many other complicated and expensive instruments and sets of apparatus are necessary. Among them are machine guns, gun mounts, synchronizers, bomb racks, bomb-dropping devices, bomb sights; radio, photographic and oxygen apparatus; electrically-heated clothing, lights and flares. The cost of such additional accessories would bring the total cost of equipment for a plane to several thousand dollars, depending upon the exact type of plane. But these devices are not essential to actual flight, and so will not be discussed in detail here.

When the American air program began to be developed none of the instruments so vital to the service was being produced in quantities and some of them were not being produced at all. Over 60 per cent of these instruments had to be developed from foreign models, and the remaining 40 per cent was secured by modifying or remodeling American automobile-type instruments. Numerous and serious difficulties were encountered in designing instruments, capable of quantity production, of the lightest possible weight and under exacting requirements as to accuracy. During this pioneer work new instruments were being developed abroad almost daily, each new design carrying an improvement.

Most of the work in this connection was done by the Signal Corps in conjunction with manufacturers. All available information and data were collected, foreign and domestic models and types were carefully tested, designs were standardized, and specifications prepared. Results show that types for every class of instrument were adopted and put into large production here. Far greater standardization was reached than existed concurrently in Europe tending to increase quantity production materially and decrease the number of replacement parts necessary.



© Brown and Dawson.

Building Uncle Sam's Air Fleet

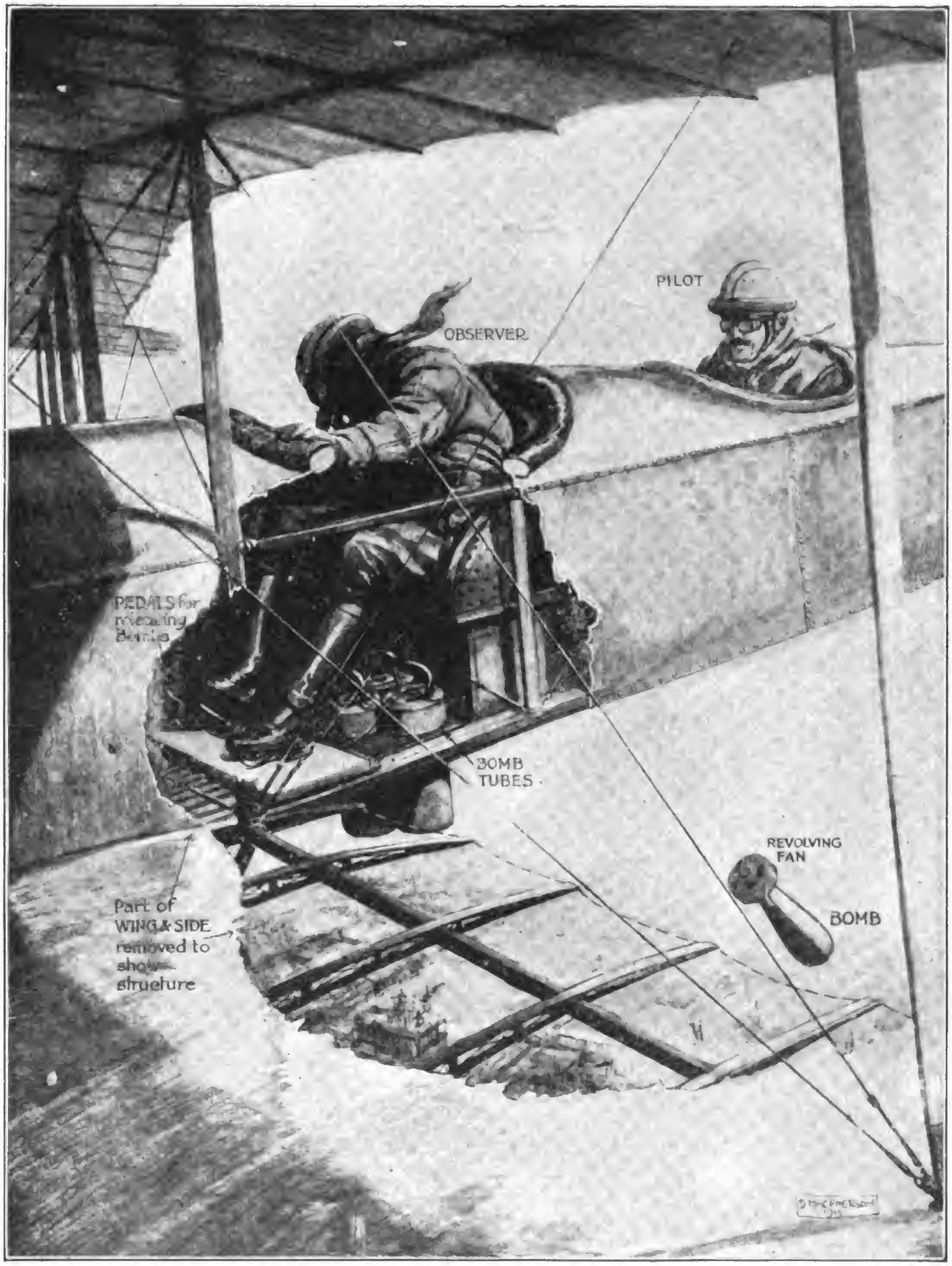
The assembling consists of erecting the fuselage, and installing seats and controls, tanks and instruments. After the motor is mounted, the body is covered with linen and given the same treatment as the wings. Note the appeal to the worker's conscience.

Quantity production on the scale necessary demanded the enlargement of all existing sources of supply and the creation of many new plants and factories. A certain amount of time was available before it was necessary to use these instruments on planes in service—the planes themselves had to be built. Accordingly, orders were placed from three to eight months ahead of requirements, but only in such quantities as would insure a steady production, owing to the certainty of improvements in the various designs.

The early plans of the production department developed from two to five sources for each instrument. This was done both as a safety measure and as a means of placing future orders on a strictly competitive basis.

Various instruments developed by the Signal Corps include:

The *tachometer,* or revolution counter, is an instrument which indicates the number of revolutions per minute at which the engine is running. Unlike the speedometer of an automobile, it does not translate the revolutions into miles per hour; another instrument gives the speed in relation to the air. When instrument matters were taken up in July, 1917, no tachometers were manufactured in this country of the type which has proved most successful abroad; namely, the escapement or chromatic type. Two large manufacturing companies got to turning out these instruments in large quantities, one of them 100 a



The Bomb-Dropping Apparatus of the German Aviators

Details of the "Noland" bomb-dropping apparatus as worked from a German bi-plane.

day, and a third company had also in production a new centrifugal type.

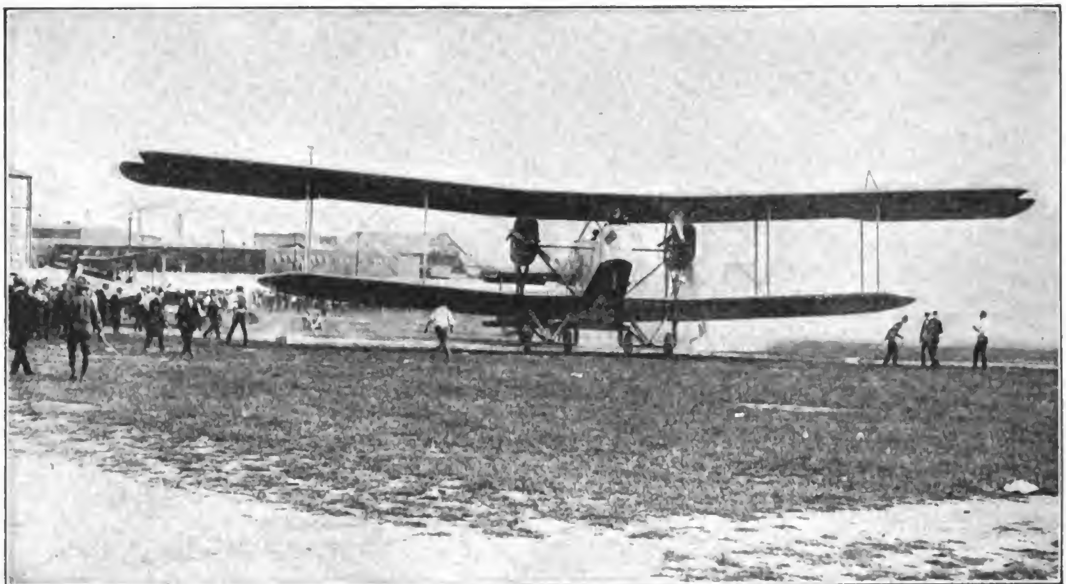
The *air speed indicator* is a pressure gauge for showing the speed of the plane in relation to the air, not the earth. This instrument includes what is known as a Venturi-Pitot tube, which is fastened to a strut and takes in the air from ahead. The air sets up a corresponding pressure in an auxiliary tube, which is calibrated and indicated on a dashboard recording pressure gauge.

The *altimeter* is an aneroid barometer, graduated to read height above the earth, instead of pressure. Under standard specifications a reduction in weight and size was effected in the manufacture of these instruments, which were finally produced in large quantities and of a quality equal to the best foreign make. Three standard types are made, with ranges of 20,000, 25,000, and 30,000 feet.

The *airplane compass,* after much experimental work, did not reach the perfection desired. A new type, having advantages over any present form of compass, especially as to compactness, was adopted. In the development of this instrument an effort was made to reduce the weight to the safest possible minimum and to decrease the space occupied.

Airplane clocks, thanks to the development which had been made in time-pieces for automobiles, were not difficult to secure. It was only necessary to standardize a design of mounting in order to adapt such clocks to airplanes.

Instrument-board *pressure gauges* were already manufactured here in large quantities, and as soon as standard specifications were developed production started. Two types are used, one to register the air pressure which forces the gasoline to the engine and the other to show the pressure produced in the oiling system by the oil-circulating pump. Standard forms of cases and dials with interchangeable glasses and bevels were designed.



© Engineers Society.

A Handley-Page Bombing Plane

The twin liberty engine type.

The *radiator thermometer* is mounted on the instrument board, where it indicates the temperature of the cooling water in the engine. Undue heating shows that the engine is not running properly or that more water is needed. Thermometers of this type made here were submitted to extensive tests. Efforts were also made to stimulate the trade toward developing more accurate and reliable instruments, and eventually a sufficient supply was available from two sources.

An instrument used to show when a plane

is correctly banked in making a turn is the *banking indicator.* Spirit level, balance, and gyroscopic types came into use. The problem of indicating the extent to which a plane is inclined to the horizontal in the air is a very complicated one. No simple solution has yet been reached. Fortunately, it is not often necessary to determine whether the plane is exactly horizontal, except when engaged in bomb dropping.

The *Aldis sight,* which is used in connection with fixed guns firing through the propeller, has been copied as regards its optical features from an English instrument; but the construction was modified in such a way that the behavior of the instrument in actual use was unquestionably very much improved. After a number of tests and experiments satisfactory instruments were made available. The makers were assisted in recomputing the lenses to suit the optical glass available in this country. The illumination of these sights for night operation was also studied.

In connection with the design of all these instruments it was found possible, without delaying production, to standardize them to a much greater extent than had been done abroad. In this way the number of necessary replacement parts was reduced to a minimum, and a uniform type of dial was adopted which, as to legibility, was easily equal to the best that had so far been used.

Among other things, safety belts for pilots, observers, and gunners were designed and placed in production; radio and photographic apparatus, ordnance devices, and oxygen apparatus were likewise developed and put in course of manufacture.

PLANES AND THEIR GROUND TARGETS

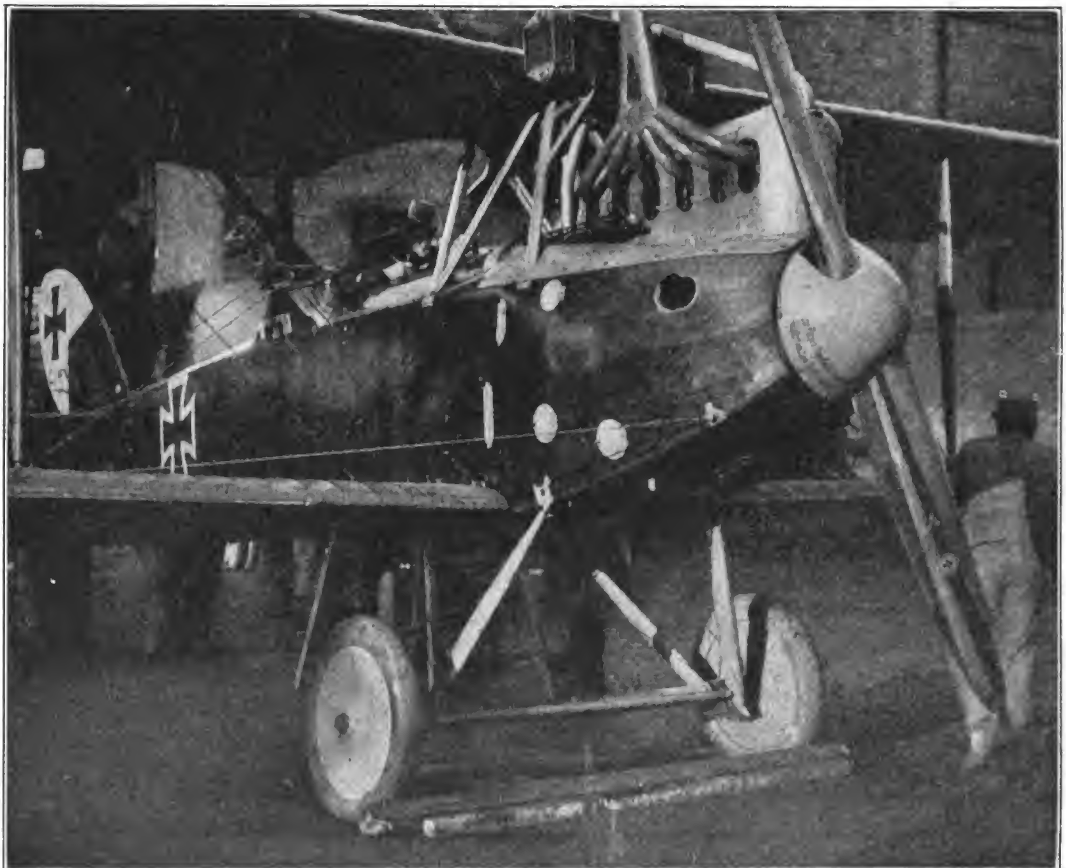
How Aerial Bombing Became an Exact Science After Four Years of Aerial Warfare

THE last year of fighting was a bombing year. Both sides were prepared on January 1, 1918, to carry on an extensive bombing campaign as the consummation of their constant improvements in aerial bombing, and in order to answer urgent military calls for long-distance bombardment. The Allies were ready with their Handley-Page, Caproni, Caudron, Breguet, A. V. Roe, Letord, Morane-Saulnier, and other bombing planes, while the Germans were prepared with their fleets of Gotha, Friedrichshafen, A. E. G. and Lizenz types. And from the first day of 1918 the bombing fleets were active; the Allies devoted much attention to bombing German military establishments and war industries, while the Germans were actively engaged at their old sport of bombing hospitals, cities and villages, and other targets quite outside the realm of military life, for the most part.

Leaving aside the propriety of German bombing tactics, the fact remains that the enemy had developed some excellent types. His early Gothas generally measured 80 feet in wing span, carried three men for a crew, and were provided with twin engines of 450 to 520 horsepower. It has been said—and no doubt with very good reason—that the Gotha type was copied after the British Handley-Page. In truth, both bombing planes are very similar, although the Gotha is a pusher while the Handley-Page is a tractor. The fact remains that a Handley-Page landed behind the German lines during 1915, and the Germans, with characteristic thoroughness, did not fail to assimilate the best ideas incorporated in what was no doubt the prototype of the modern bombing plane.

But the Germans, with more ambitious bombing raids in view, most likely the bombardment of American stores and landing places far behind the fighting lines, set to work on larger bombing planes. They employed larger Gothas, known as the Friedrichshafen type, and introduced the A. E. G. twin-engined bomber, which, while carrying a power plant similar to the Gotha, is built largely of steel as compared to the all-wood construction of the

latter. In fact, steel is largely employed in the wings of the A. E. G., and some fine welding work is to be found in those specimens which were shot down by Allied forces. The A. E. G., however, is somewhat smaller than the Gotha, measuring but 60 feet in span. It carries a crew of three, as in the case of the Gotha.



Courtesy of Scientific American.

The German "Albatross" Airplane

In the course of the summer of 1918 the French brought down a giant bombing plane near Villers-Cotterets, which, although largely burnt, was studied by aviation experts with good results. Following the usual erroneous practice, this bomber has been called a Gotha by the press accounts; but there seems good reason to consider it as one of the Lizenz type, intended for extra long flights. At any rate, this bomber measured 140 feet in wing span, 64 feet from the nose to the tail, 20 feet in height. The wings were 10 feet in chord and were spaced over 12 feet apart. The bomb racks, placed to the left and right of the central nacelle, contained 2,000 pounds of bombs. The power plant consisted of four Maybach motors of 260 horsepower each, or a total of 1,040 horsepower. The motors were divided into two pairs, and in each pair they were arranged in tandem. One engine of the pair served to drive a tractor screw in front, while the other turned a propeller at the rear. Two and a quarter tons of bombs could probably be carried by this machine, and the crew probably numbered nine men. This arrangement is not unlike that of the latest and largest Handley-Page four-engined bombers of Great Britain. In fact the machine appears to be outclassed in the ability to do this work only by the British giant.

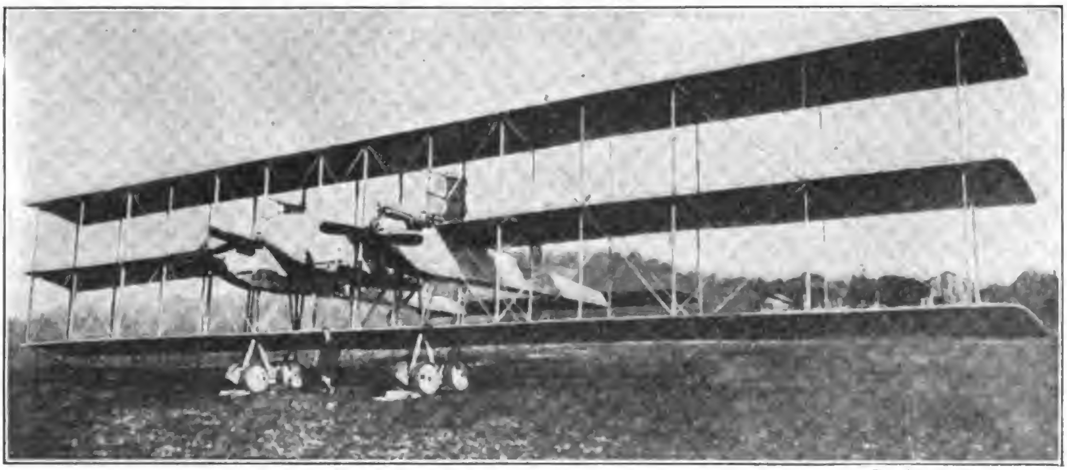
GIANT MACHINES FOR CARRYING DEATH-DEALING CARGOES

Turning to the Allied side, one is at once attracted to the Handley-Page and the Caproni types. The former has been constantly increased in size although the general design has remained about the same. The latest models are provided with four high-powered Rolls-Royce engines as compared to the earlier twin-engined models totaling in the neighborhood of 800 horsepower. The Handley-Pages have done excellent work in the way of long distance raids, and there can be no doubt that they would have bombed Berlin in a thorough manner if the armistice had not upset all plans.

The Caproni type, of Italian conception, was perhaps the largest machine in use by the Allies. The huge triplane model, fitted with three Fiat or I. F. engines, two located in tractor position at the front end of each fuselage and one pusher at the rear of the central nacelle, is capable of carrying nearly 3,000 pounds of useful load such as bombs. The engines are generally of 200 horsepower each, or a total of 600 horsepower. But it is generally understood that the Italians have developed larger Caproni triplanes; indeed, good authority has it that they have triplanes capable of carrying three tons of bombs. However that may be, the Italians did excellent work with their Capronis in raiding Pola, Trieste and other Austrian military and naval centers.

Among the other lesser known bombers on the Allied side were the Letord, Morane-Saulnier and Caudron types of the French air service. The Letord is a twin-engined biplane tractor using the Hispano-Suiza engine. The planes are staggered backward and the struts are run vertically backward at the tops. Five wheels are used in the landing gear. The Morane-Saulnier, on the other hand, is of more conventional design. It is also twin-engined and of the tractor type. It is provided with either the rotary Rhone engine or fixed Hispano-Suiza. The Caudron, if anything, is better known than the two foregoing types, having been employed by the French, British and Italians for some time back. It is equipped with two rotary Rhone engines carried in small nacelles between the planes, on either side of the central nacelle. No fuselage is employed; instead, four outriggers running back in line with the engines carry the tail members while the lower pair acts as landing skids.

The Voisin bomber is, perhaps, the pioneer type of bombing plane, dating its service in this branch of aerial activity back to the uncertain days of 1914. In general appearance the Voisin has maintained its original characteristics. It is provided with one engine



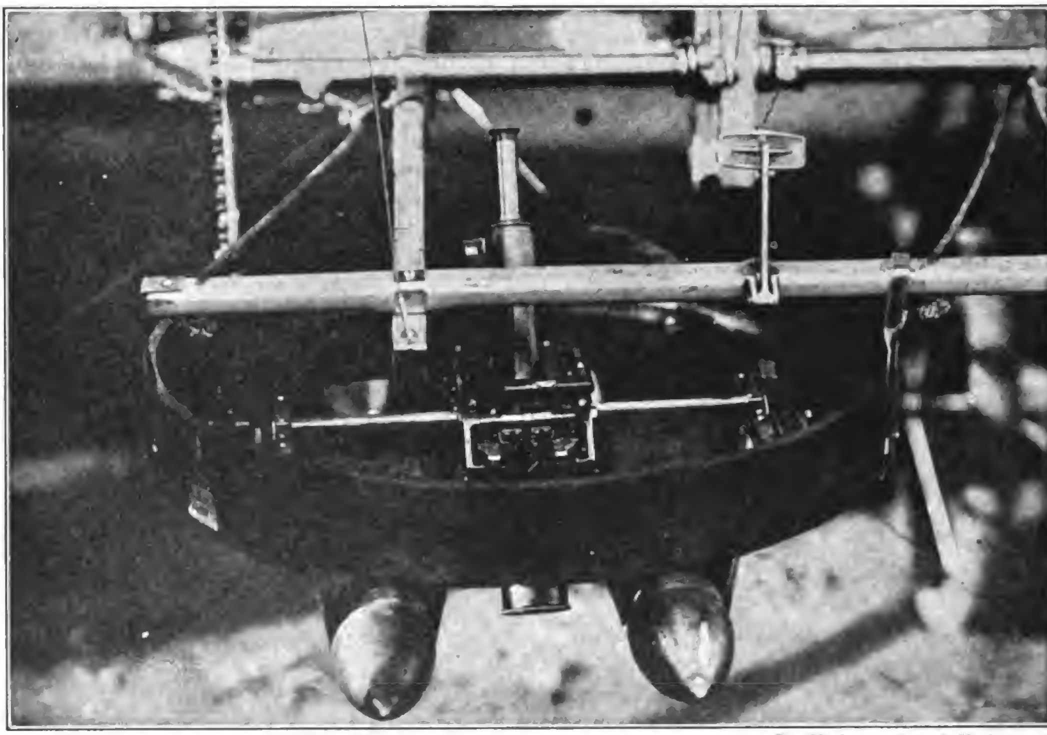
© Photo by Levey.

Caproni Tri-Plane

One of the Italian types of airplanes that did effective service against the Austrians.

mounted at the rear of the nacelle, driving a propeller. A fixed Peugeot, Renault or Salmson engine is employed. The balanced rudder and balanced elevator are carried on four outriggers which terminate in a vertical chisel edge.

The Breguet is a bomber of the pusher type, equipped with a single Renault engine. It has outriggers of the Caudron type, more or less. The gasoline tanks are carried on either side of the central nacelle, which is quite characteristic of this type.



© Underwood and Underwood.

Bomb-Carrying Device

Invented by former Lieutenant Scott. This photograph shows the bombs in position and the range-finder.

Of late the British have made use of A. V. Roe bombing planes which, in general appearance, are somewhat suggestive of the Handley-Page, although smaller. This type has a central fuselage, and twin engines arranged in small nacelles on either side. Sunbeam, Green or Rolls-Royce engines are used.

BOMBS AND HOW THEY ARE AIMED

Turning from the bombing planes to the bombs, since the latter, after all, are the business end of all bombing operations while the former are but the means to the end, we find that remarkable progress has been made. In the early days of the war the bombs were quite small. Airmen merely raised them over the edge of the airplane and dropped them on the target, sighting with the naked eye. But with the necessity for greater accuracy and with the ever-increasing size of the bombs, it became necessary to devise accurate bomb sights and positive bomb-dropping gear.

As for bomb-dropping gear, it is sufficient to state here that these vary greatly in design, ranging from the bomb racks of the German machines to the elaborate superposed bomb racks of some Allied machines. In the earlier bombers the missiles were released vertically, whereas ultimate practice was to release them horizontally in line of flight.

From the very beginning of the war the Germans employed special airplane bombs rather than artillery shell as did the Allies. And this practice, be it admitted, has been

quite correct. For artillery shell must needs be designed with a high percentage of the weight devoted to the steel container of the explosive, in order to meet the factor of weight as called for by ideal ballistics. In aerial work, on the other hand, the main requisite is explosive effect, and the matter of ballistics can well be relegated to second place. If a shell falls, it is going to fall and that's the end of it; we need not worry about accelerating its fall; nature attends to that. Thus the Germans employed aerial bombs whose explosive content represented 60 per cent. of the total weight, while in their 77 mm. shell the explosive was but 5 per cent. of the total weight.

The German bombs, to give their authors due credit, were well designed, with torpedo-shaped bodies and tail fins. The latter prevented the missile from tumbling during flight, kept it nose-on toward the target, and gave the missile a slow rotation. The bombs were made in many sizes, with the largest of 100, 200 and 600 pounds, approximately. The fuse employed was ingenious, and could readily be changed by the bomber from a contact or impact fuse to a time fuse. When the Germans attacked such establishments as railroad stations, arsenals, villages and so on, they made use of the time fuse setting, so that the explosive got in its greatest damage. Against living targets and light material, so to speak, use was made of the impact setting, so that the bomb fragments were scattered far and wide.

It must not be supposed that the Germans had a monopoly of aerial bombs. While the Allies did, in the absence of specially designed bombs, make use of adapted shell during the earlier stages of bombing work, they developed suitable aerial bombs which were quite effective, as the inhabitants of Essen, Coblenz, Mannheim and Frankfort are in a position to testify only too well.

BOMBING AND BEING BOMBED

Bombing was being carried on extensively by both sides in the closing months. Each side raided the other almost nightly, for it was practically impossible to prevent enemy air raids. The only defense was to raid the enemy; it was a case of "tit for tat"; and where he dropped one bomb on your side you had to drop two, three or ten on his until he had enough. The various anti-aircraft defenses were of some value, although they failed to prevent raids from being at least partially successful over a given period. What is more, enemy air raids, if they are to be combated properly, unfortunately tie up a certain number of machines for patrol and combat work, which are thus unavailable at the front. With a view to lessening the number of machines required for anti-aircraft work, the Germans and the French, and most likely the British, tried using steel nets suspended from kite balloons for ensnaring raiding airmen. The scheme, according to reports, was not successful; in the specific case of Paris the nets proved a flat failure. The main trouble appears to be the expanse of the sky, only a small portion of which can be screened off even with the largest of steel nets.

The two sides during the last three months concentrated on their work of reciprocal bombardment. Important railroad stations, aviation fields, munition depots, barracks, storehouses, industrial establishments, seaports, interior cities—all these were receiving more and more attention. Most of the raiding was at night, although during big offensive operations the bombing was carried out in daylight. During the Piave battle in particular, the bombing planes were employed to aid the defense, acting as long-range artillery. Bridge after bridge thrown across the swollen stream by the Austrians was blown up by Italian bombers.

THE SUPER-SEARCHLIGHT

The greatest advance in the art of making searchlights may be attributed to Sperry, whose name occurs elsewhere in connection with the gyroscope. He devised a way for maintaining a little hollow or "crater" in the end of the positive electrode of an arc; and he filled this crater with incandescent gas. The result, after the arc had been formed, was a light of extraordinary intensity—about three times as bright as an ordinary arc light produced without the crater. The luminous gas acts as a point source of light, and both on this account and because of its greater brightness than the plain arc it gets its superiority.

SNAPSHOTS FROM THE SKY

The Interesting and Vital Work of Photographing the Enemy's Activities From a Fast-Moving Airplane

THE consensus of expert opinion, as expressed at the various inter-Allied conferences on aerial photography, is that at least two-thirds of all military information is either obtained or verified by aerial photography.

Marshel Foch withheld his final decision, governing the operations immediately following the St. Mihiel offensive, until his staff had received and examined the aerial photographs which confirmed the nature and strength of the new line established by the victorious American troops. General Pershing has stated that the aerial photograph is the most reliable source of information available to the higher staff officers.

PHOTOGRAPHS THAT SAVED THOUSANDS OF LIVES

An infantry colonel referred to the aerial photographs he received during the Argonne offensive as the most vital assistance he had ever been given by the Air Service, and said the details of the action as worked out by his command from the study of these photographs had contributed in a large measure to the success of the action and had been an important factor in reducing casualties. A young lieutenant, in speaking of his experiences in action near Vaux, said that the only data he had there that was worth a "tinker's damn" came from three aerial photographs some one had "policed up" for him.

As another side to the question, it is but fair to note the following remark by a colonel of the infantry: "They sent me some of that stuff (referring to aerial photographs) but I couldn't make anything out of them." The answer in this case is obvious, for the value and meaning of aerial photography has been definitely and conclusively established, and the success with which aerial photographs can be exploited is measured by the natural and trained ability of those concerned with their study and interpretation. The aerial photograph is in itself harmless and valueless. It enters into the category of "instruments of war" when it has disclosed the information written on the surface of the print. The average vertical aerial photographic print is upon first acquaintance as uninteresting and unimpressive a picture as can be imagined. Without considerable experience and study it is more difficult to read than a map, for it baldly represents nature from an angle we do not know, continues Major Edward J. Steichen, A. S. A., Chief of Photographic Section, U. S. Air Service, A. E. F., writing in the *U. S. Air Service.*

The oblique aerial picture, especially when taken from a low altitude, is more readily comprehended, and sometimes striking pictorial effects are produced. The vertical photographs made by the day bombing squadrons occasionally present a spectacular and dramatic interest in addition to their value as a record of the bomb raid.

TAKING THE MYSTERY OUT OF AERIAL PHOTOGRAPHS

There has been a tendency to wrap the technique of aerial photography in a veil of secrecy and mystery. This attitude may have been useful in stimulating curiosity, but there comes a time when such a pose seriously interferes with the free development of a new process. Let it be clearly understood that the chief difference between the family photographs in the old, red-plush album on the parlor center table and a batch of aerial photographs on the council table of staff officers at the front is that the latter are simply better photography.

While aerial photographs can be made with a vest-pocket kodak, it is obvious that where

© Underwood and Underwood.

"Death Chamber" of Bomb-Dropping French War Plane

Above the two rows of bombs is a rapid-firing gun mounted on a revolving wheel. The shells are released from the bottom of the airplane through a chute.

special conditions prevail new instruments and methods must be created to meet these conditions. The work accomplished along these lines during the war stands as a remarkable scientific and mechanical achievement. This achievement, coupled with the courage, skill and endurance displayed in taking and producing the amazing quantity of photographs required, makes up a chapter that is second to none in the annals of photography.

A good aerial photograph compares favorably with the best technical landscape photographs. The latter can be leisurely made from a carefully chosen point of view with a camera firmly set on a tripod, and with lens and exposure conditions offering a considerable latitude. The military aerial photograph is made with a heavy, cumbersome camera more or less successfully suspended in the fuselage of an airplane traveling through the air at a good hundred miles per hour. The fuselage receives all the vibrations of a powerful motor whirring off more than a thousand revolutions a minute, as well as the thumps and bumps of air-pockets and exploding enemy anti-aircraft shells.

The ground photographer chooses his weather; the General Staff chooses the aerial photographer's weather. The weather conditions during both the Argonne and St. Mihiel operations were exceptionally poor. The most favorable days were crammed with photographic activity, and even days with barely enough light to produce the faintest trace of an image on the photographic plate had to be "photo days."

Most of the long distance photographic-reconnaissance missions were the work of the First Army Observation Group, to which was attached Photographic Section No. 2. It is doubtful if there was a better or more efficient outfit for the producing of aerial photographs in any of the combatant armies. Throughout the entire period of operations the enemy never was able to carry on long range reconnaissance with anything like the system or regularity which prevailed here.

The photographic missions went out on schedule, like an express train service. The "big price" was often paid, but from all available data the enemy more than "got his" in return, and also learned to know this group not only as an observation unit but as a formidable fighting machine. Their photographs were all made from an altitude of about 5,000 meters, and the quantity and quality of the work produced were remarkable.

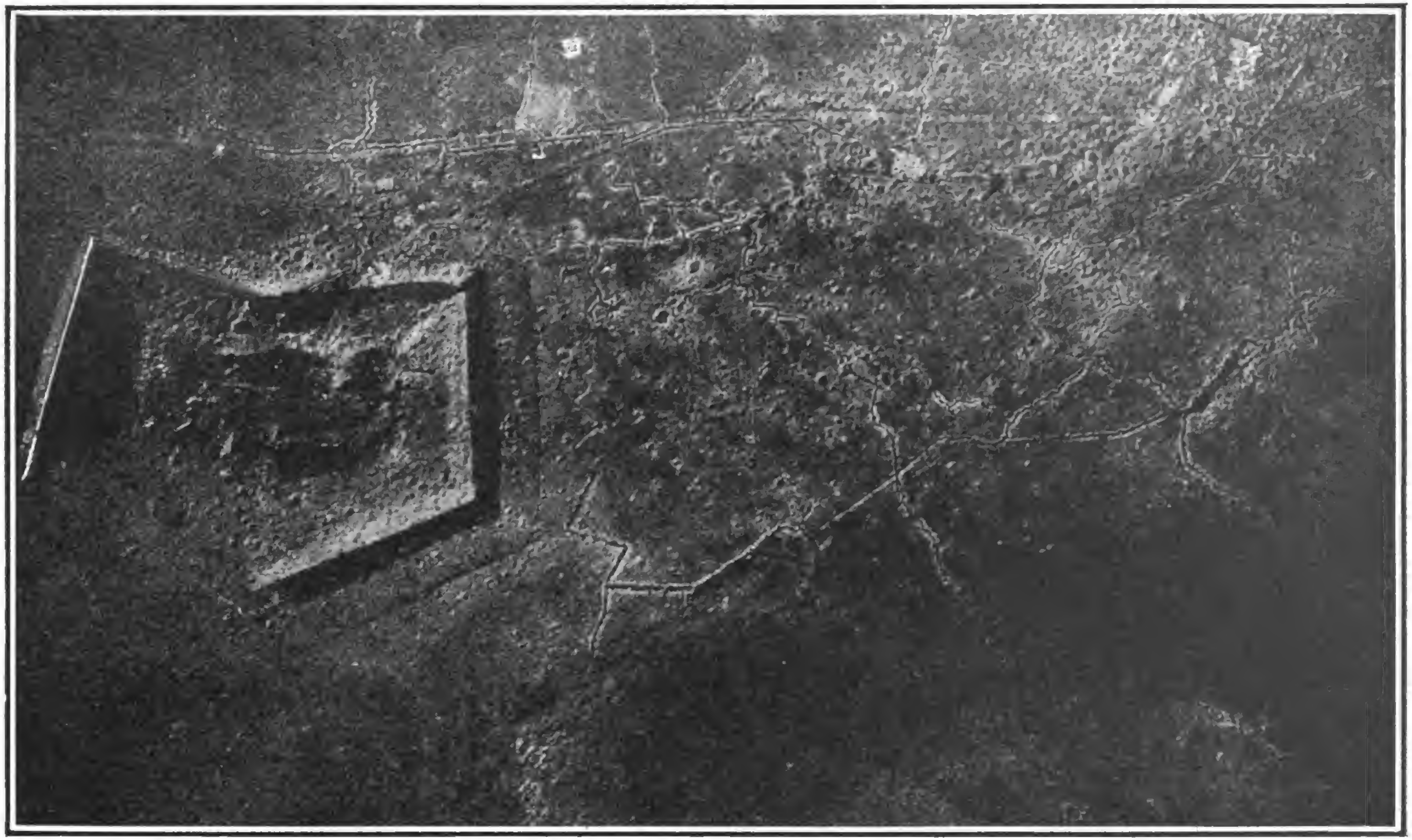
RECOGNITION NOT FROM FRIENDS BUT FROM THE FOE

Photographic reconnaissance is a most difficult and ungrateful part of aerial observation. It gets more recognition and credit from the enemy than any one else. Captured enemy documents indicate that their General Staff was very much worried about the Allied aerial observation, and particularly the planes with the all-recording camera soaring miles up in the air overhead.

The American photographs were practically all produced with 18 x 24 centimeter (about 7½ x 9 inches) cameras. This camera is a simple metal box fitted with a 20-inch lens and focal plane shutter; the plates are carried in magazines with a capacity of 12 plates. These cameras, and as a matter of fact 87 per cent of all the photographic equipment and materials employed at the front, were purchased in France.

During a mission over the lines the operation of this camera took up all the attention of the observer. From the beginning of our experience, it was clear that an automatic camera was not only desirable, but would eventually become a necessity. All of the Allied armies had been working on a camera of this kind; numerous interesting experimental instruments had been evolved, but the production of a satisfactory apparatus was slow in materializing. Only during the last month of the war were we able to place 15 automatic cameras in operation over the lines.

These cameras were ingenious instruments invented by Lieutenant De Ram, and were built under his supervision in a small shop near Paris. The camera works entirely automatically; it can be set for any given interval of exposure and simply requires to be started when the airplane reaches the region to be photographed. It has a capacity for 50 exposures. In spite of the fact that this machine was new in principle and that these first cameras could scarcely have been considered final or complete, results were produced that were not only valuable in themselves, but pointed



Aerial Photograph of Fort Douaumont

the way to new and hitherto impossible accomplishments in aerial photography. Unfortunately the camera could only be installed in the Salmson planes, as the U. S. D. H.-4 planes then in France were designed to carry the small cameras used in training and not the larger instruments in use at the front.

WHY THE AUTOMATIC CAMERA WAS USED

On one occasion two planes were sent out on a photographic mission; one was equipped with a De Ram automatic and the other with a hand-operated camera. During the mission these two planes were attacked by seven enemy ships; two of the enemy machines were brought down, the remaining five quit. The observers in the planes naturally made good use of their machine guns, but the plane with the automatic camera also continued ticking off pictures throughout the fight and they brought back a perfect reconnaissance without a single gap in the series.

The significance of this kind of a performance is even more important than the result, and with the prospect of soon receiving similar and possibly better automatic cameras that were being produced in America, there is no doubt that within a few months aerial photographic methods would have been completely changed. As it was, these few De Ram cameras were the first entirely automatic cameras successfully employed by any of the Allies over the lines.

The automatic camera is not only a logical factor in mechanical efficiency, but it eliminates an unnecessary risk of life.

This is exemplified by the photographic reconnaissance of the 99th Squadron, which came to be known in the Photographic Section as the "13th hour mission," the pictures having been made about one o'clock. The Intelligence Staff had made an urgent request for photographs of a certain part of the Hindenburg system. Weather conditions delayed this work for some time. Several attempts were made and finally one of the planes ran into a clear space over the prescribed area, but at the same time a group of enemy planes appeared.

Both pilot and observer realized the importance of getting these pictures, and the observer, deliberately disregarding danger, kept on operating his camera and completed the mission. The pilot, though slightly wounded, was able to get his riddled ship back home.

When the plane landed the observer was found dead, his body fallen forward against the camera. A bullet had gone clean through the camera and then through his heart, but orders had been complied with. The magazine containing the plates was intact, and when developed the "13th hour mission" produced one of the finest sets of photographs made in the A. E. F.

When the airplane returns from a photographic mission the real labor of the Photographic Section begins. The greatest speed compatible with photographic quality is desirable. The exposed plates are hurried to the laboratory, developed, washed, and dried; then two proofs are run off from each plate. These are identified and located on the map and given a preliminary interpretation. Sometimes this interpretation reveals information that is promptly reported to Headquarters over the telephone. These first prints from a mission were normally produced in from one to two hours.

In urgent cases, when chances could be taken with quality of results, this time was considerably shortened, the record being 24 finished prints, from the first 12 plates developed, delivered to the Branch Intelligence Officer in slightly less than half an hour after the plane had landed on the field. Spectacular stunts of this kind were not often required or encouraged. They were furthermore often impossible, due to so simple a reason as lack of transportation for the heavy plate magazines from the field to the laboratory when this happened to be located quite a distance away.

SEVENTEEN THOUSAND PRINTS IN ONE DAY

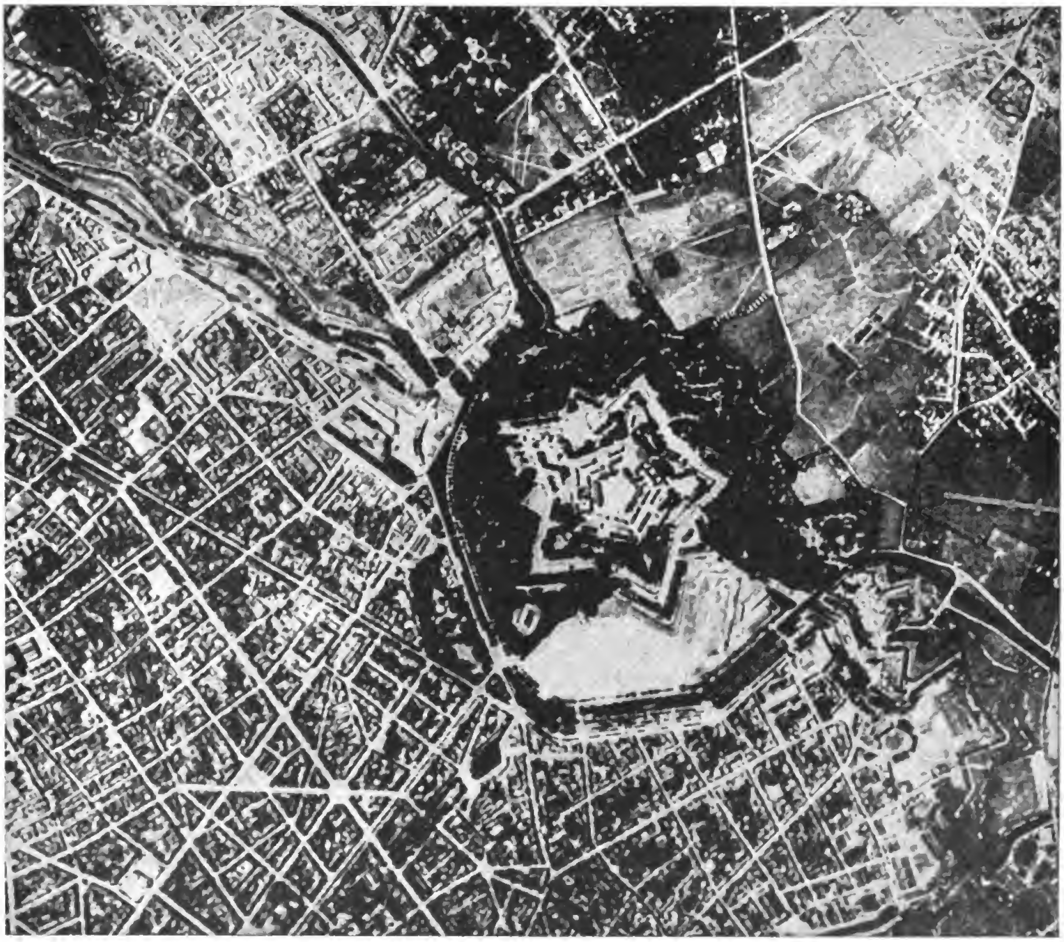
The real speed problem consisted in getting out the great mass of prints required from the negatives made each day. In this connection the American Photographic Service set a pace which was not equaled. The printing record goes by a small margin to Photographic Section No. 1. This section produced 17,000 prints in one day—16 actual working hours.

This would be an achievement if the work had been done in a perfectly equipped laboratory, but under the primitive conditions at the

front and with all the water carried in buckets from a neighboring well, it is another one of the many examples indicating that the American Expeditionary Forces made good chiefly on the inherent ability of the American soldier, plus his go-to-it, stick-to-it ability.

The only laboratory facilities a photographic section was ever reasonably sure of was its photographic truck and trailer, which latter contained a tiny dark-room and drafting-room. The dark-room served admirably for plate development, and sometimes for making proofs; but something had to be found, stolen or imagined to serve as a printing laboratory, and a cowshed or a dug out might be called into service for this purpose.

In July, during the Château-Thierry offensive, a photographic section had to resort to a tent for a work-room. Inside of one end of the tent a wooden framework was set up and this covered with tar paper and opaque curtains to make it light-tight. It was also just about as air-tight, but men worked steadily in shifts in this hotbox for six consecutive days and nights—and came out alive. The three prints referred to by the young lieutenant of Vaux came out of this "laboratory," and so did all the other American photographs that were used in the Château-Thierry operations.



An Airplane View of Lille

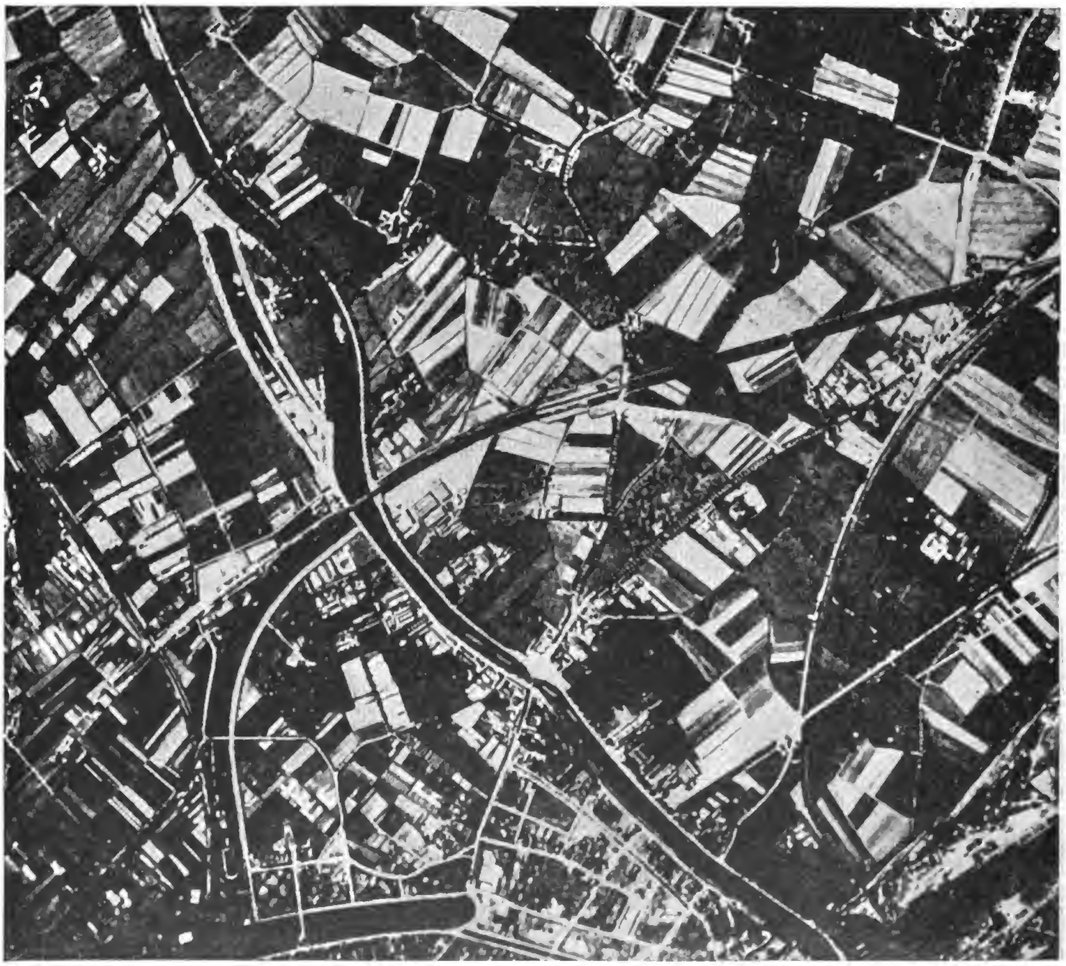
SETTING UP SHOP WITHOUT LOSS OF TIME

Late one afternoon General Mitchell called for another photographic section. Within an hour's time the nucleus of a section was or-

ganized and equipped from such casual replacement personnel as was available in the vicinity of the First Air Depot. These men were all just fresh from the training-schools, and without any previous experience in the field. They traveled all night and got installed in an outhouse of a brewery at Ligney-en-Barrois by daybreak, where they promptly set up shop and commenced work like old-timers.

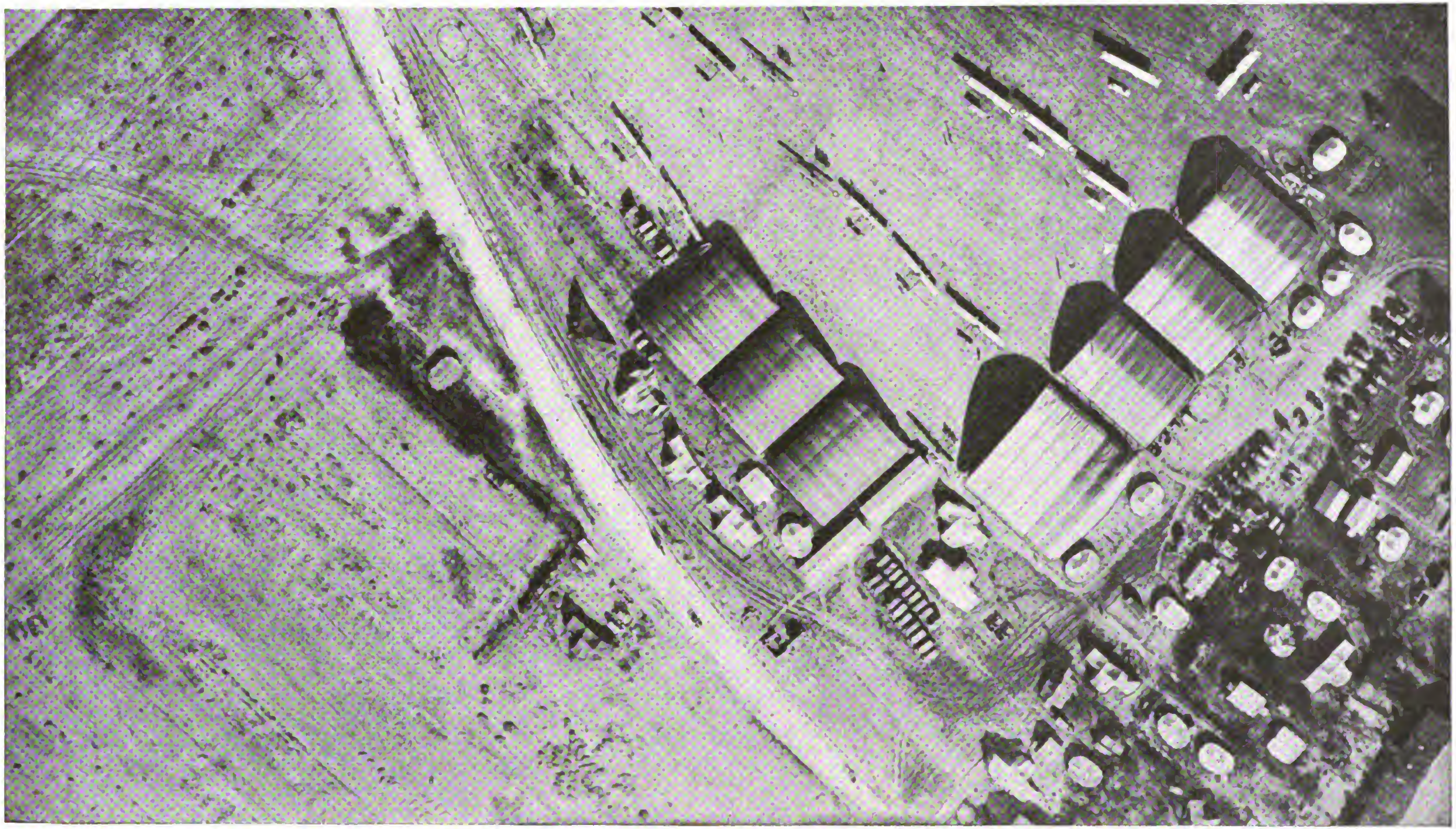
At 10 o'clock of the same morning on reporting the arrival of the section to the General, and being questioned as to how long it would be before this section would be in shape to produce, Major Steichen was able to report that 1,000 prints had already been delivered. These boys kept at it for five days and nights, without more than four hours sleep out of any twenty-four, and produced over 50,000 prints.

Whereas photography over the lines was currently entrusted to observers, the best photographs, from a technical standpoint, were made by such photographic officers as were occasionally detailed to do the work.



View of the Belgian City of Bruges from an Airplane

Captain A. W. Stevens, while Commanding Officer, Photographic Section No. 6, volunteered to do several particularly difficult missions while in the region of Fismes. He mounted his camera on the machine gun tourelle and made the pictures from an altitude of but a few hundred meters. Numerous dangerous and troublesome machine-gun nests were located on these pictures, which all previous photographs had failed to show.



The Aviation Camp Near Verdun

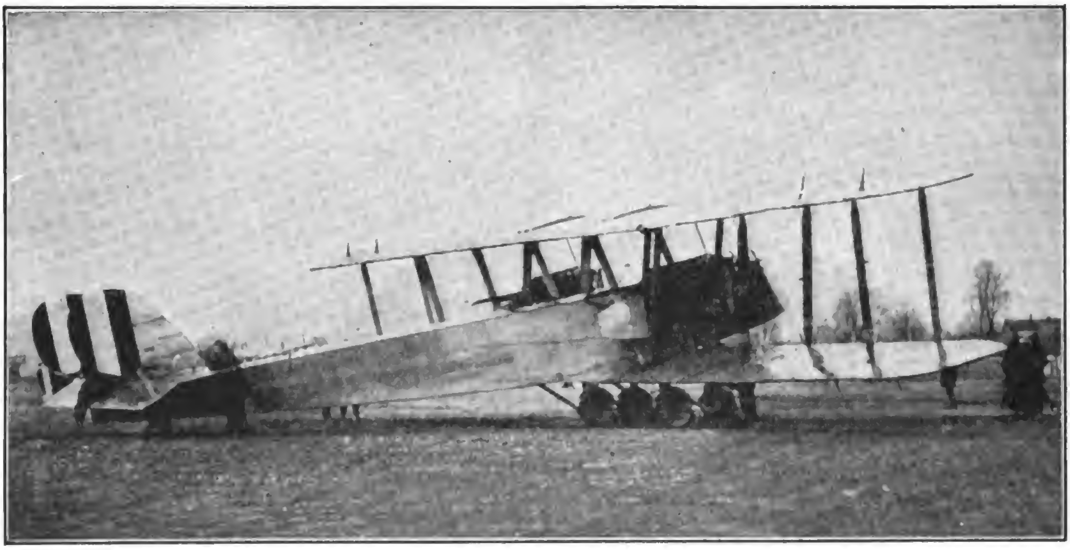
His work, as well as the photographs taken by several of the other non-combatant photographic officers, present a conclusive argument that in all cases where special photographic requirements or conditions have to be met the trained and experienced photographer is a better man for the work than the regular aerial observer.

SOME FIGURES REGARDING OUR PHOTOGRAPHIC SECTION

At the time of the armistice, the personnel of the Photographic Section, Air Service, in the A. E. F., numbered 55 officers and 1,111 soldiers. The efforts of these men individually, as units, and as the Photographic Section of the Air Service, constituted a definite factor in fighting and winning of the war. The total production of photographs after July 1, 1918, was 1,300,000 prints.

Much of the equipment furnished was primitive and the materials available became progressively worse. The influence of this factor of quality of materials can be measured by the fact that, when a few batches of the new panchromatic plate arrived from England the quality of our photography was raised by at least 50 per cent., and this quality was further improved upon in the work done when American plates and paper finally became available in the necessary quantity.

The practical experience gained by these photographic soldiers in learning to surmount all kinds of technical and material difficulties, coupled with the excellent photographic training they received at the specialized schools in America and in France, brought them back to America as an asset to American photography. They represent a new and specific value to the American photographic industry, if this industry will be shrewd enough to recognize their worth.



The Huge Martin Bombing Plane

The largest American designed land machine ever built in this country. Its motive power is two Liberty engines of 400 horse-power each.

WHAT OF THE FUTURE OF AERIAL PHOTOGRAPHY?

The future of aerial photography is naturally bound up with the future of the Air Service, and as a function of the Air Service is full of possibilities as a peacetime development. Not only will aerial photography render great assistance in mapping the United States, but it brings to the process of mapping, and by the simplest of means, a wealth of detailed information that would ordinarily be excluded and perhaps even impossible. Numerous government agencies interested in mapping will participate abundantly in the

advantages of aerial photographic mapping, if the work is properly undertaken.

The nature, quality and quantity of the timber in our forests can be accurately measured by making aerial photographs of these forests in the autumn. Each kind of tree assumes a characteristic color at this time of the year, and by the use of appropriate selective color screens and panchromatic plates these color tones can be separated and subsequently the proportion of each tone measured. In this manner the quantity of each kind of timber in a given area can be readily estimated, and if necessary or desirable the individual trees could even be counted. In fact, the American army made a feature of experimental work in this direction, sending distinguished physicists on long and repeated observation flights over all sorts of country, in the effort to amass a fund of data which should be of immediate value for the war-time purposes of scouting.

A recent experiment in locating, by aerial photography, areas infected by the boll weevil in southern cotton fields is another example of the innumerable large and small possibilities which suggest themselves for the exploitation of this process for commercial and educational purposes. And then there is the case of the bee farmer who had suffered great losses by poisoning of his bees, and who, at small cost, hired an aviator to help him locate the danger zones with the result that none of his bees were poisoned that year.

Getting Aerial Photographs from the Front

The man shown in this photograph is assembling a group of tiny photos made from a British airplane for the purpose of constructing an aerial map of the enemy territory.

OUR N-C BOATS

Describing the Navy-Curtiss Flying Boats Which Were Successfully Used in the Trans-Atlantic Flight

THE first direct steps in the building of the N-C flying boats were taken soon after the entrance of the United States into the World War. In the summer of 1917 Rear Admiral D. W. Taylor, chief constructor of the navy, considered combating the submarine menace with large flying boats. He made a recommendation to Naval Constructor J. C. Hunsaker embodying this idea. As a result on September 9, 1917, Glenn H. Curtiss of the Curtiss Aeroplane & Motor Corporation was summoned to Washington. Discussion and design went forward from the time of Mr. Curtiss's arrival on the following day, and actual construction was begun early in 1918.

Aircraft like the Navy-Curtiss boats, however, cannot be thought of as products of a sort of spontaneous mental combustion. They have a history antedating themselves. To understand what they represent one must comprehend what went before them.

THE BEGINNING OF THE FLYING BOAT

The forerunner of the flying boat was the hydroaeroplane. This flying type was developed at Hammondsport, N. Y., and at San Diego, Cal., in 1909, 1910 and 1911. Here Mr. Curtiss invited representatives of the United States Army and Navy to visit his headquarters on North Island, San Diego Bay, for flying instruction, and the successful trials carried on early in 1911 were accordingly witnessed by Lieut. T. G. Ellyson, later Commander Ellyson, as the first officer detailed by the Navy in connection with aviation. Shortly afterward the present Commander John H. Towers and Commander H. C. Richardson were detailed under Lieutenant Ellyson, and flew at Hammondsport, N. Y., soon after the first flying boat made its appearance. This craft was developed as a result of the hydroaeroplane experience. Work upon it was begun at Hammondsport in 1911 and then the first model was flown at San Diego early in 1912.

The U. S. Navy in May, 1911, gave the following specifications for a hydroaeroplane:

> A hydroaeroplane, capable of rising from or landing on either the land or the water. Capable of attaining a speed of at least fifty-five miles per hour, with a fuel supply for a four-hour flight. To carry two people and be so fitted that either person could control the machine.

These specifications were met in the first model constructed by the Curtiss Aeroplane Co. at Hammondsport, N. Y., between May and July, 1911. This seaplane was the official forerunner of the N-C-1's, continues *The Journal of the Society of Automotive Engineers.*

The first flying boat was a natural simplification of the hydroaeroplane in that fuselage and pontoons were merged into a boat serving both as body and landing gear. The additional surface in contact with the water and the more radical changes with relation to the disposition of machine elements which the boat represented, forbade its being attempted first, though the idea of it had existed as long as that of the hydroaeroplane. When the latter, little more than a land machine on pontoons, had cleared away difficulties of equilibrium, engine placement, etc., the flying boat followed. The first model had a sled-form profile, a flat bottom turning up to form a wedge-shaped nose, and was driven by a pusher eight-cylinder, 80-hp. Curtiss engine mounted between the two wings below the center panel.

During the early development of the water craft the Navy men, favoring the hydroaeroplane rather than the flying boat, placed sev-

eral orders for hydros and used them for training pilots for several years.

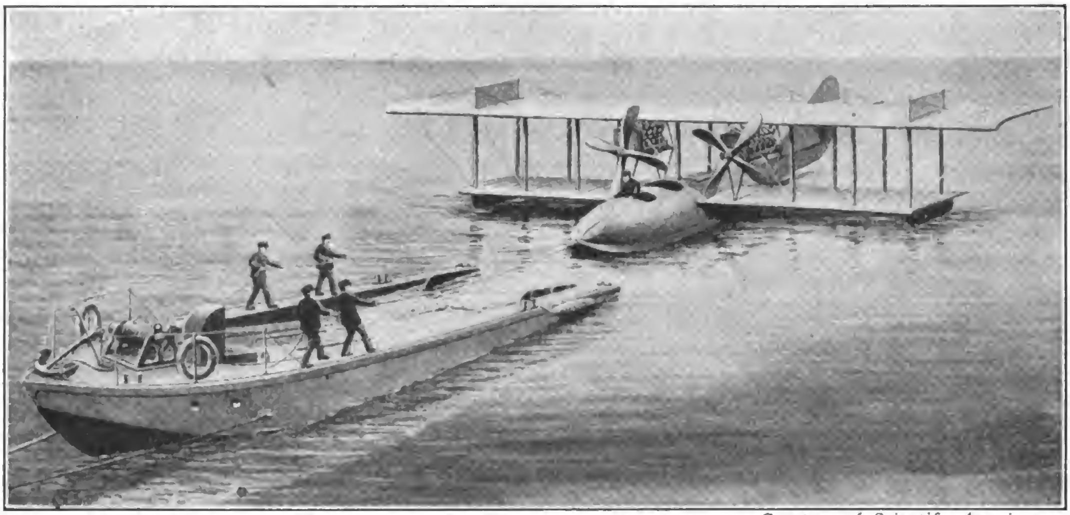
Finally Mr. Curtiss, always an enthusiastic flying-boat advocate, convinced them that this type of water plane offered more advantages and succeeded in winning them over. This happened about the time of the beginning of the World War when the Curtiss Co. had begun to furnish large flying boats to England, Russia and other foreign countries.

Although the hydroaeroplane was taken up by European producers, the flying boat seems to have remained an American type until after the beginning of the war in August, 1914. It was then, through Lieut. J. C. Porte, brought to the attention of the British Admiralty, and flying boat construction was begun in Europe. After the first several experimental machines, the flying boat was called Model F. This machine attained sufficient reputation to attract attention in aeronautical circles. It was employed by the United States Navy in connection with the Vera Cruz expedition of 1913, present Commander P. N. Bellinger distinguishing himself by a series of brilliant observation flights over Mexican territory from the American fleet.

Late in 1913 Rodman Wanamaker became interested in the idea of a flight across the Atlantic Ocean. He decided upon the seaplane as having obvious advantages over an airplane for such an attempt, and consulted Glenn H. Curtiss, the designer of greatest experience with marine flying types, with respect to the construction of a craft which might be expected to succeed in the contemplated aerial voyage. Lieut. J. C. Porte, temporarily retired from Admiralty service, was to pilot the new machine.

One of the requirements of any transatlantic plane was obviously a large supply of gasoline. It was also highly desirable that a mechanician as well as a flyer should make the voyage. A two-engined job accordingly seemed the logical type. Mr. Curtiss's design was a flying boat with two 100-hp. Curtiss engines, carrying a useful load of 1,800 pounds, and having a span of seventy-five feet. A third engine was subsequently added.

Although the outbreak of war in August, 1914, prevented the *America* from starting for the Azores, it did not lessen the importance of the model as a step forward in flying boat design. Nothing like it had heretofore appeared, and its size and multi-engine equipment became the attributes of a series of flying boats



Courtesy of Scientific American.

A Ferryboat for Long-Distance Bombing Planes

It was a long, long journey from the British air stations to German ports. Accordingly, the British worked out a simple system of carrying their seaplanes on lighters, of the type here shown, to a point near the city to be raided, so as to conserve fuel and the nerves of their pilots. These lighters were towed by destroyers.

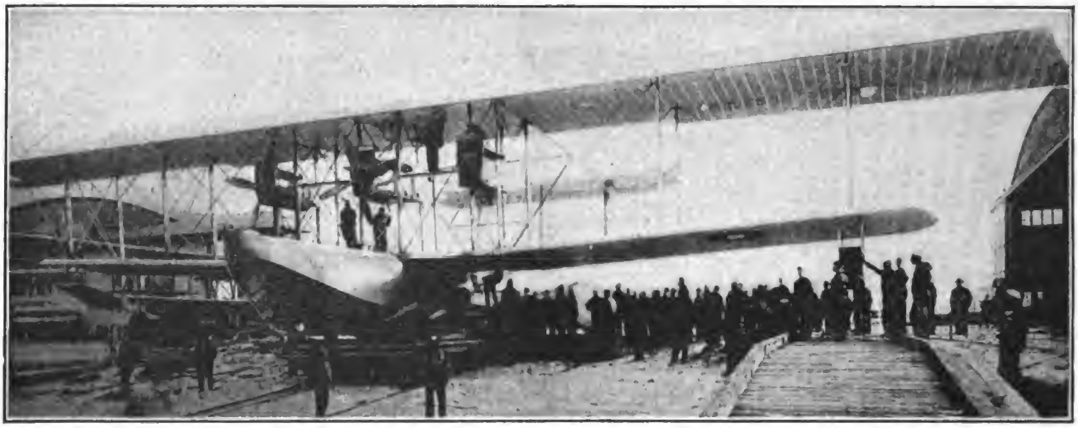
which were to lead toward the achievement represented in the Navy-Curtiss models.

BRITISH STIMULUS TO AMERICAN DESIGN

The British Admiralty, as has been stated, early in the war authorized the designing and construction of large flying boats. Of the several which were constructed in the United States, the most memorable was the Curtiss Model T. This was a triplane of a 133-ft. wing spread, mounting four 300-hp. V-4 Curtiss engines. Its size suggests the N-C's, the latter being of slightly less wing spread but of greater engine power.

together with two engineers, Messrs. Gilmore and Kleckler, were for the next three months in constant touch with Dr. A. F. Zahm, Naval Constructor C. G. Westervelt and Naval Constructor H. C. Richardson. The ideas of all conferees were pooled. The sole desire was then and has since been to produce an effective flying boat.

Preliminary work went forward at Buffalo, where the Curtiss plant was located, and where Commander Westervelt had established headquarters, and at Washington, where Dr. Zahm and Constructor Richardson were carrying on experiments. Dr. Zahm constructed a three-foot model of the new air-



The *N-C-1*—A Navy Seaplane

This is a sister ship of the *N-C-4*. The *N-C-4* successfully completed the transatlantic voyage, and was the first air machine to perform this feat.

craft. This model he carefully tested in the Washington Navy Yard wind tunnel, determining scientifically the exact size and arrangement of the tail surfaces needed, and the behavior of the machine from the standpoints of equilibrium and stability. Constructor Richardson experimented in the model basin of the Navy Yard with respect to hulls. He obtained interesting and valuable results. The final hull was the third model tested by Constructor Richardson. Each model showed an improvement with respect to its effect upon the water, the final design passing along the surface at high speed with a remarkably slight disturbance. Naval Constructor McEntee and W. L. Gilmore of the Curtiss Co. contributed valuable assistance with regard to the N-C hull.

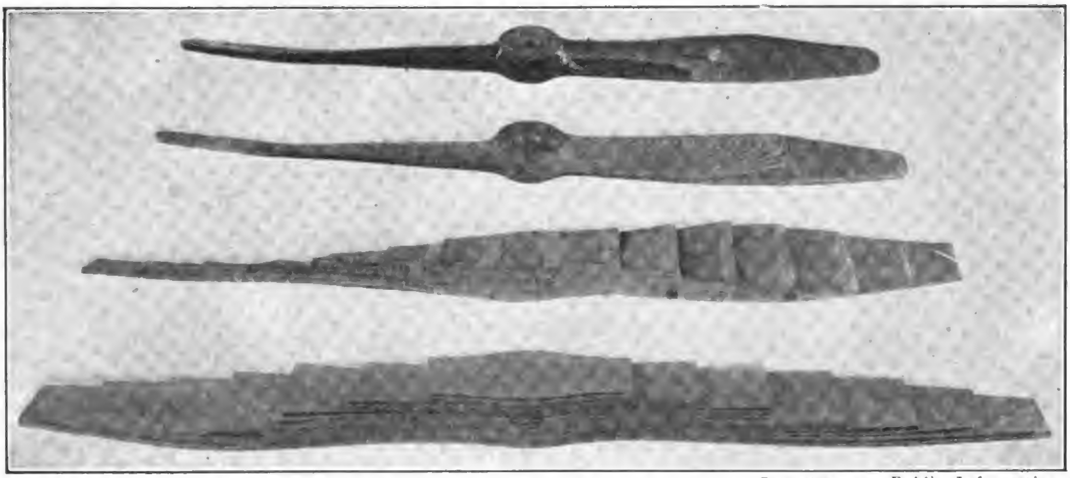
The vessel was an interesting forerunner of the N-C type, differing from it in certain details, in one instance vitally, but forming a basis for progress. The hull, for instance, was extended rearward to form a support for the tail surfaces. It was found that such an extension in a flying boat of this size was inadvisable, and the shortening of the hull and the mounting of the empennage on outriggers in the N-C boats was a result of this discovery. The models H-7, H-12 and HS had given valuable experience in flying boat construction which was used in connection with the N-C design and production.

The summons of September 9, 1917, brought the Curtiss representatives to Washington. Here they conferred with officers of the United States Navy. Glenn H. Curtiss

FOUR NAVY-CURTISS BOATS AUTHORIZED

It had been decided to call the new flying boat the "Navy-Curtiss" or "N-C," the name indicating the joint responsibility for the craft. Design work had been actively prosecuted since October, 1917. In December, 1917, authorization was given by the United States Navy for the construction of four N-C's. As the N-C was still an experimental machine in that a full-size model had yet to be constructed, the designs for the new flying boat were brought to Garden City, N. Y., where the experimental plant was located, and actual construction on all four boats was, with the exception of work done on contract, carried on at that place. The Navy had its headquarters at the plant, and supervised the production in all its stages.

The *N-C-1,* the first of the four ships to be completed, was flown October 4, 1918. It will be appropriate while speaking of its performance, to indicate definitely its place in flying-boat history. The N-C boats represented the crystallization of past experience of both the Navy and the Curtiss organization, embodying, as they should, certain important changes. The shortened hull, giving greater strength and less resistance, and the mounting of tail surfaces on outriggers were the two most radical alterations from past designs. The employment of Liberty engines should be mentioned, however, these being three in number, each developing 330 horsepower, and consisting of three tractors, one in the center and one on either side. These engines were mounted between the wings. Another feature of interest was the all-aluminum gasoline system installed. Box-section beams were also used for the first time in a large aircraft. The box tail system, comprising three rudders and two vertical and horizontal stabilizers, represented another new practice. It may be stated that the controls, considering the size of the machine, were thought to operate with remarkable ease and to respond to the pilot's touch with unusual quickness. Finally, the disposition of guns was so effected that the completed machine had no "blind spot." The boat was protected from attack from below by guns mounted over the side.



Committee on Public Information.

An Airplane Propeller in the Making

The successive steps in the manufacture of an airplane propeller are here shown. It will be noted that a propeller is made up of a number of strips or laminæ, which are glued together and gradually carved to the proper size, shape, and perfect balance.

The *N-C-2* was under construction before the *N-C-1* was finished, work having been begun upon it in the summer of 1918. It was different in details, some of them experimental, from the *N-C-1.* The engines, for instance, comprised one pusher and two tractors with the pusher in the center instead of three tractors. This was considered a slight improvement over the earlier mounting.

More important was the installation of all engines so that they were not involved in the structure of the machine. The new mounting would not allow any engine to jar or crush or even to break from its own bracing, though any of these results would be highly improbable and the last practically impossible, without affecting the inter-panel bracing. Later the *N-C-2* was equipped with four engines and these were arranged in two tandems of one tractor and one pusher each. The tandem arrangement was preserved in the final engine mounting of the *N-C-1*, *N-C-3* and *N-C-4*, which have two engines in tandem below the center panel, and a tractor engine on either side between the wings. The two-tandem arrangement was successful and may be resumed in later types. The incorporation of two engines in one nacelle obviously cuts down resistance, doing away with two nacelles in a four-engine job.

The *N-C-3* and the *N-C-4* were constructed between the autumn of 1918 and May, 1919. The *N-C-3* originally had two tractors and one pusher, later three tractors and one pusher. The *N-C-4* followed the latter arrangement from the start, as the decision to add a fourth engine had been made with the trans-Atlantic trip in view before the *N-C-4* had progressed to the point of engine installation. The *N-C-1* was changed to follow the three tractor, one pusher arrangement, and the *N-C-2*, as is known, was sacrificed to repair the damage suffered by the *N-C-1* in a severe storm off Far Rockaway in March, 1919.

The addition of a fourth engine affected the general design of the boats to no appreciable extent. A total weight of about 1,500 pounds was added, however, and a carrying capacity of 1,800 pounds net gain was secured. The four-engined boats lifted 28,000 pounds. It may be profitably remembered that the larger the boat the greater the load in proportion to size.

With the fourth engine also came an increase in speed from a maximum of eighty miles per hour at 22,000 pounds to a maximum of ninety-five miles per hour with a loading of 24,000 pounds.

The original *N-C-1* holds the world's record for passenger carrying with a total of fifty-one persons carried. It was noted for the ease with which it negotiated long over-the-water trips. All that the original *N-C-1* did, the present N-C boats can do, and more.

THE CLIMAX

The story of the trans-Atlantic attempt of the N-C boats is too well known to require extensive description here. Suffice it to say that three boats made the attempt, the *N-C-1*, *N-C-3*, and *N-C-4*, under the command of Commander Towers, U. S. N. The route followed was from Rockaway, Long Island, to Trepassey, Newfoundland, thence to the Azores, with another jump to Lisbon, and finally to Plymouth, England. The boats were not entered for prizes of any kind; the whole idea back of the attempt was to prove the trans-Atlantic seaworthiness of the type, and to obtain for the United States the glory of being the first to achieve the trans-Atlantic flight.

The *N-C-1* and *N-C-3* broke down on the way to the Azores, when within ready reach of those islands. The *N-C-4*, however, in command of Lieut.-Commander Read, reached the Azores safely and later proceeded to Lisbon and Plymouth—the first airplane to cross the Atlantic.

The N-C boats, of course, did not participate in the war. But they were designed and given the ability to cross the ocean as a very direct result of the war, and must be listed among the achievements of the war. With them as its climax, a current estimate of the war work of the American navy was put forth in the following terms:

The heroic work of the American Navy has thus opened an aerial route overseas. It has also demonstrated that even in unfavorable weather large flying boats can attain difficult objectives, and that where it would be suicide for a land machine to fly, it is possible for the seaplane. The great boats and their skilful and daring crews stand on the threshold of greater achievements. With only seven years of mechanical life behind them, including ancestry, the N-C's and aircraft like them have done enough to suggest that their possibilities represent a mine of transportational efficiency, only the surface of which has been scratched.

THE CASE FOR THE AIRSHIP

Fundamental Advantages and War-Time Progress That Brought the Lighter-than-Air Type to the Forefront of Aeronautics

IN stating the case for the airship it is really impossible to give the subject an adequate defense without entering into a controversial discussion with the advocates of heavier-than-air machines. Although the features of airships and airplanes are so widely different that each type of aircraft promises to cover quite different fields of usefulness, the impression prevails at large that the airplane will eventually displace the airship, be it for military or commercial purposes.

This wholly erroneous impression does not take into account the extraordinary development that took place in airship construction during the war period, and which was kept even more secret than airplane progress.

PROGRESS MADE SINCE 1914

Before discussing the more general problems of lighter-than-air craft with respect to their possible use in times of peace and war, some figures will be given to show at once the great progress realized in this domain during the World War. As Germany was, at the signing of the armistice, still leading in airship construction, though closely followed by Great Britain, two German naval Zeppelins, the *L-3* and the *L-71,* will be taken as representative of the stage of progress in 1914 and in 1918.

From the *L-3* to the *L-71* the gross, or total, lift has increased from 30 to 66.64 tons; the disposable lift, or useful load, from 8.5 to 38.84 tons; the efficiency ratio, that is, the ratio of disposable lift to gross lift, from 27.3 to 58.3 per cent; the total horsepower, from 800 to 2,100; the full speed at 10,000 feet, from 50 to 77.6 miles per hour; the cruising endurance, at 45 miles per hour, from 20 to 177½ hours; and the static ceiling, that is, the altitude that can be reached by purely static means, from 6,000 to 21,000 feet.

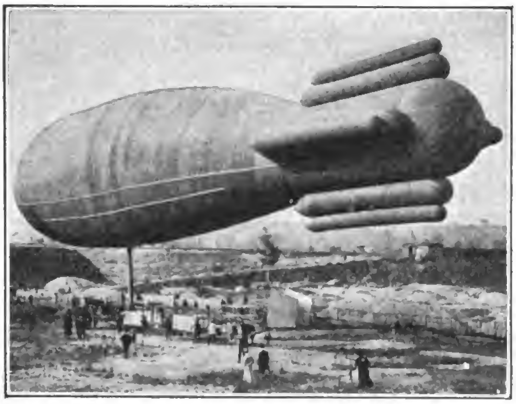
The most impressive of the above figures are, to my mind [the author of this discussion is Ladislas D'Orcy, writing in *Aviation and Aeronautical Engineering*] the ones showing the increase in efficiency ratio, which has about doubled with the twofold increase in capacity of the Zeppelin, for this well illustrates the one very important feature of lighter-than-air craft which confers upon them a superiority over heavier-than-air craft, namely, that an increase in the size of airships gives greatly improved efficiency. In airplanes, on the contrary, efficiency not only remains stationary with the sizes now reached, but is even likely to decrease with further increase in size. In fact, the best all-around plane of 1914 showed an efficiency ratio of 36.3 per cent. against 36.1 per cent. for the 1918 machine of equal rank; so that there has actually occurred a slight loss of efficiency, and it can be said that this would have been greater but for considerable improvement in design.

The reason why in an airship the efficiency ratio is improved with an increase in size, whereas in the airplane it remains at best stationary, is due to the fact that the airship derives its lift from volume, while the airplane derives its lift from area. Now, in either case what may be termed the unit of lift, cubic feet of volume or square feet of area, exerts only a definite lifting effect; in the airship this is determined by the specific gravity of hydrogen or helium, and is therefore immovable, whereas in the airplane it depends upon progress in design, and is thus still open to improvement. This fact may, in a certain measure, work out in favor of the airplane, but there are other factors which actually limit the practicable size of heavier-than-air craft.

One of these is that while the lift of an airplane theoretically varies with the square

of linear dimensions, the weight of the wing structure per unit of area does not remain stationary with an increase of wing area, but increases, because the larger wing structure must be made proportionally strong. Consequently, a size is eventually reached where every additional square foot of surface weighs as much as it can lift, so that beyond this size there will occur a marked reduction in efficiency.

Now we know that the strength of similar structures is inversely proportional to their linear dimensions. This rule applies equally to airships and airplanes, but while the lift varies as the cube of dimensions in lighter-



Courtesy of Scientific American.

When Dirigibles Were New

The French "Ville de Paris" dirigible of a dozen or more years ago, when dirigibles were still in their infancy.

than-air craft, and as the square in heavier-than-air craft, an increase in lift is attained in airships with much less increase of dimensions than in airplanes. For instance, if we double the span, and, to retain the same aspect ratio, the chord of a given airplane, the lift will increase four times, while theoretically the weight will have to be eight times as great if we want to obtain the same structural strength. But in an airship, when we increase the lift four times, we increase the length of the structure only by the cube root of four, that is, approximately one and a half times, so that the weight of the structure will be only four times greater for the same proportionate strength, which is to say that the weight of an airship is, for the same structural strength, directly proportional to the total lift.

Now, it is true that, as heavier-than-air advocates contend, the law of geometrical similitude is not strictly applicable when aircraft are increased in size, because more suitable materials become available for constructing large machines, or else, available materials can be used in a more advantageous form. However, this rule applies to lighter-than-air craft as well as to heavier-than-air types; and it must be conceded that even with allowance for improved efficiency due to more suitable materials of construction, the weight of an airplane *does* increase in a greater proportion than the lift, at best like three to two, always provided the same structural strength is desired.

Another technical advantage afforded by the airship is that the so-called coefficient of tractive resistance, that is, the ratio of the weight of machinery to total lift, obviously decreases with an increase of size, because the lift varies as the cube of the linear dimensions, while the resistance of the air and the brake horsepower vary as the square of the dimensions, all other things being equal.

The British National Physical Laboratory has made an exhaustive investigation of the tractive resistance of airship hulls, as the result of which some mighty interesting figures are now available. These are based on the streamline hull of the Zeppelin *L-33*, which was brought down in England in the fall of 1916. It appears from these figures that the tractive resistance decreases in a marked degree with an increase in size and a *proportionate* increase in horsepower. Thus the coefficient of tractive resistance of a 60-ton rigid, which is about the largest airship of 1919, is 1.9 per cent. at 45 miles per hour, 3.8 per cent. at 60 miles per hour, and 7.7 per cent. at 80 miles per hour, as against that of a 300-ton rigid, which is 0.9 per cent. at 45 miles per hour, 1.8 per cent. at 60 miles per hour, and 3.6 per cent. at 80 miles per hour. In other words, a 300-ton rigid can fly more economically at 80 miles per hour than a 60-ton rigid can at 60 miles per hour.

This explains why the performance of the latest Zeppelins, which have almost trebled in size since 1914, has so marvelously improved. One such performance, which has re-

cently been made public by the British Air Ministry, and cannot, therefore, be taken for enemy propaganda, fittingly illustrates the tremendous possibilities of the large rigid airship in long distance aerial transport. In the fall of 1917 the German Admiralty ordered one of its airships to undertake a relief expedition in behalf of the German force that was surrounded by the Allies in East Africa. Accordingly the naval Zeppelin *L-59*, after having been loaded up with some twenty tons of munitions and stores, left Jamboli, Bulgaria, at 8.35 a. m. on November 21st, heading for East Africa. The airship proceeded as far as Khartum, Egypt, which she reached in the early morning of November 23rd, when she received a radio message from the German Admiralty, ordering her to return, as the force to be relieved was reported to have surrendered. The *L-59* thereupon put back to Jamboli, where she arrived without any untoward incident on the morning of November 25th, having covered in the course of her four-day cruise a distance estimated at 4,500 statute miles or 7,300 kilometers.

POSSIBILITIES OF LONG DISTANCE FLIGHT

As the shortest distance between America and Europe, from St. John's, N. F., to the southwest coast of Ireland, is somewhat less than 2,000 English miles, it is obvious that an airship of the *L-59* class could, with the crew of twenty-two and some twenty tons of cargo she carried on that memorable cruise, easily cross the Atlantic both ways without even refueling. In view of such a voyage the best airplane performance naturally dwarfs to a considerable degree; nor is there anything extraordinary in the report that the Zeppelin Company is engaged in building an airship of 115 gross lift tons and 2,400 horse-power, which will carry 100 passengers, forty-five tons of cargo, and thirty tons of fuel and provisions across the Atlantic.

I now propose to answer some of the principal objections which are made against the use of airships in passenger transportation, for I do not think any one familiar with the subject can deny their great potentiality as a military weapon since American chemists have successfully overcome the problem of producing a non-inflammable lifting gas, helium, in large quantities and at a comparatively low cost. One of these is that the comparatively low speed of airships makes these craft less independent of adverse winds, and, therefore, less reliable in operation on a schedule than the airplane. Airships have not yet exceeded a speed of eighty miles per hour, whereas airplanes have made speeds of over 150 miles per hour, from which the inference is naturally drawn that heavier-than-air craft will prove much more reliable and advantageous as time-savers in aerial transport than lighter-than-air craft. Arguments of this sort are, however, highly misleading, because speed alone cannot be considered the sole criterion of commercial utility; in considering aircraft for the purpose of transporting passengers and freight, the element of speed must be jointly examined with the load carried and the cruising radius.

Referring again to the figures given before, it appears that the best existing all-round airplane, the *DH-10a*, can fly at a speed of 125 miles per hour for fourteen hours, that is, in still air, over a distance of 1,750 miles; while the best existing airship, the *L-71*, can fly at a cruising speed of forty-five miles per hour for 177½ hours, or seven and one-half days, that is, in still air, over a distance of 7,987.5 miles, or, roughly, 8,000 miles. A comparison of these figures strongly emphasizes the point that the airplane is mainly a high-speed, short-distance carrier, while the large, rigid airship is essentially a medium-speed, long-distance carrier; either type of aircraft has therefore its well-appointed sphere of activity in aerial navigation. Airships can be employed to best advantage on routes exceeding 1,000 miles in length, while airplanes will prove useful on trips of shorter distances, where the time employed in putting off and taking on passengers and in refueling would curtail the saving of time effected by aerial travel.

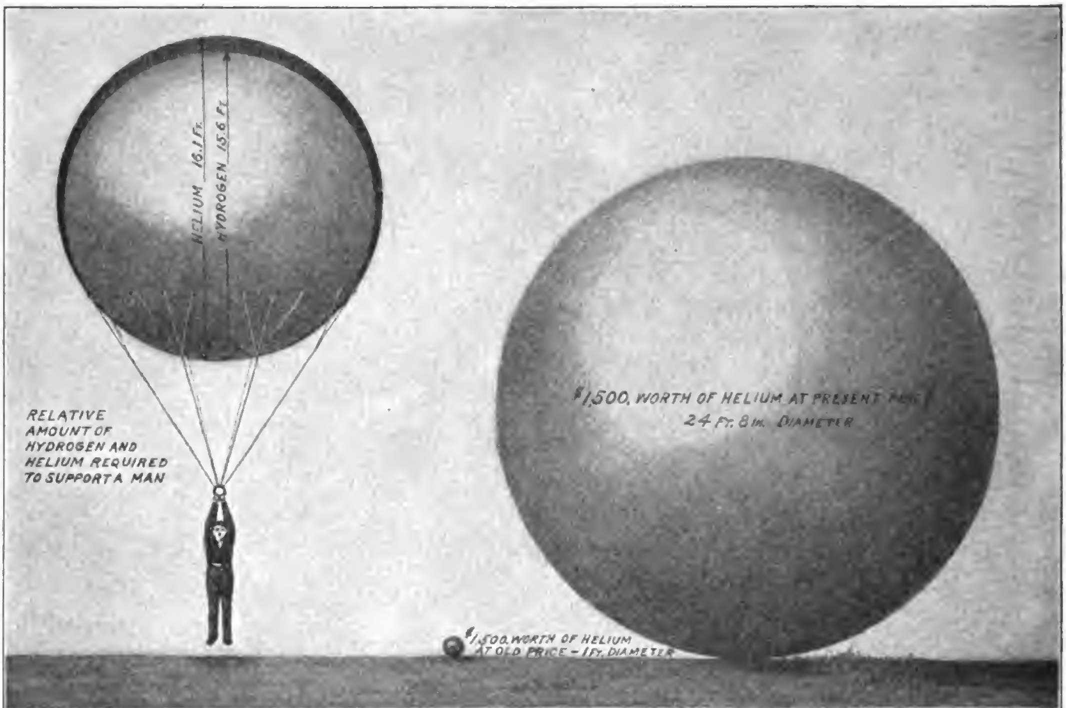
FIELDS OF AIRPLANES AND AIRSHIPS

It has therefore been suggested that airships should mainly be employed in transcontinental and transoceanic traffic, while airplanes could be used for feeding the airship terminals with passengers hailing from places several hundred miles distant. In this way the airship would compete with the steamship,

and the airplane with the railroad train; the saving of time would in either case amount to at least 50 per cent.

The great endurance and cargo capacity of airships are not, however, the only features that make them particularly desirable for the long distance transportation of passengers and freight. One of the important points in favor of lighter-than-air craft is that they afford a decidedly greater element of safety than heavier-than-air craft, because an airship can stay aloft regardless of engine failure, whereas a stoppage of the airplane's power-plant necessitates an immediate descent in gliding flight. Now, there is no inherent danger in such a descent, provided suitable landing grounds are available at given distances; but until a chain of numerous landing stations is created along the lanes of future aerial travel, some risk will be involved in public transportation by airplane, especially over wooded and marshy country and over the ocean. It is in transoceanic traffic that the greatest future of the airship seems to lie, because there competition with the existing means of transport will be much easier owing to the low speed of steamships, if compared to railroad trains, and because alighting in a stiff gale is not at all pleasant to visualize.

Still another factor which seems to favor lighter-than-air craft in public transportation over long distances is that the requirements of comfort can be attained more easily than on heavier-than-air craft. First of all, weight is, comparatively speaking, a matter of minor importance on airships because of their great buoyancy; and secondly, the large size of the hull affords better opportunities for fitting not only spacious state rooms, lounges, etc., but of fitting them so that they will be sufficiently removed from the engines and airscrews to suppress in great part the vibration and



© *Scientific American.*

Hydrogen vs. Helium

Just so long as dirigibles employ hydrogen, which is highly explosive and inflammable when mixed with air, just so long will dirigibles be dangerous. Thus chemists have been at work on substitutes for hydrogen, and they have come across helium gas. Helium is non-explosive and non-inflammable, and American inventors cut its cost in the ratio shown in this diagram.

noise. Furthermore, a promenade deck of several hundred feet in length can be provided on top of the hull. All these may seem minor matters, but they should not be overlooked, for the mere saving of time will not attract a large section of the traveling public to aerial transportation unless a sufficient amount of comfort be afforded as well.

POSITION OF UNITED STATES ON DEVELOPMENT

The question now arises, since the value of airships for commercial purposes seems to have been sufficiently outlined, where does this country stand in the development of lighter-than-air craft? To date only small size non-rigid airships have been built in the United States, and this exclusively for the needs of the Navy. These vessels subdivide into two classes, the so-called "Blimps," or submarine scouts, and the Coastal, or C-class ships; the former have a capacity of about 100,000 cubic feet and a single engine of 100 to 150 horsepower, driving a tractor or pusher screw, while the latter displace about 200,000 cubic feet and are driven by two 150-horsepower engines and twin screws. Although both types are adaptations of British designs, various improvements have been introduced in these ships by American manufacturers, particularly in the development of the larger type, which may be considered as a distinctly American product. This is especially noticeable in the rigging of the car to the hull, which is of the finger patch system on the American Coastals, whereas in the British C-class vessels the car is rigged to an internal "rope girder" which is kept in tension by the tautness of the hull. This rope girder is of triangular form in transverse cross-section, the apices of the triangles being secured to the intersection lines of the three-lobed hull.

A larger type of non-rigid airship, which the British have developed for scout work with the fleet, is the North Sea class. These ships have a capacity of 360,000 cubic feet, two 260-horsepower engines, and a full-speed endurance, at 57.5 miles per hour, of twenty hours; they carry a crew of ten. So far no corresponding type has been produced in this country, and the same remark applies to the large rigid ships Great Britain has been developing with great steadiness since the war. One of these vessels, the *R-34*, recently crossed the Atlantic from London to Mineola, Long Island, and return. It has a capacity of 2,000,000 cubic feet, five engines giving a total horsepower of 1,250, and a full speed of about seventy miles per hour; her crew numbers twenty.

French Official Pictorial Press, N. Y.

Repairing a French Dirigible

MOORING MASTS FOR AIRSHIPS

So many airships were damaged in entering or leaving their sheds, that the British late in the war sought—and found—a better means of caring for these craft when they were at rest. Tall steel masts were put up, and at their summits were fixed strong steel collars, free to turn indefinitely in either direction. The airships were then strongly moored to these collars, and left to float in the breeze like a long pennant. They at once turned into the wind, and held there, shifting as the wind shifted; the absence of anything for them to foul with made it practicable thus to moor them on high, whereas they could not have been moored at or near the surface. To test out this style of mooring, the British left one of the biggest dirigibles out for six weeks, in all kinds of weather; and at the end of that time the mooring apparatus was still in good order, and not the slightest damage had been suffered by the big gas-bag. This disposes for good of one of the knottiest points about the dirigible.

THE RISE OF THE DIRIGIBLE

Steps that Counted in the Development of the Zeppelin and the British Dirigibles, and What the War Meant in the Refining of Such Craft

GERMANY started the war with a fair number of Zeppelin dirigibles, just how many may never be known. It was no secret that Germany had a fleet of Zeppelins; for years the world had been reading of the accidents occurring to the machines of the old Count von Zeppelin. It seemed that the moment this inventor finished building one machine, it would smash, crash, be struck by lightning, or burn up. Thus there came into existence the greatest fable in aeronautics, namely, that the dirigible was no good and never would be any good as a type, and that the airplane was the only thing which held promise as a commercial and military airship.

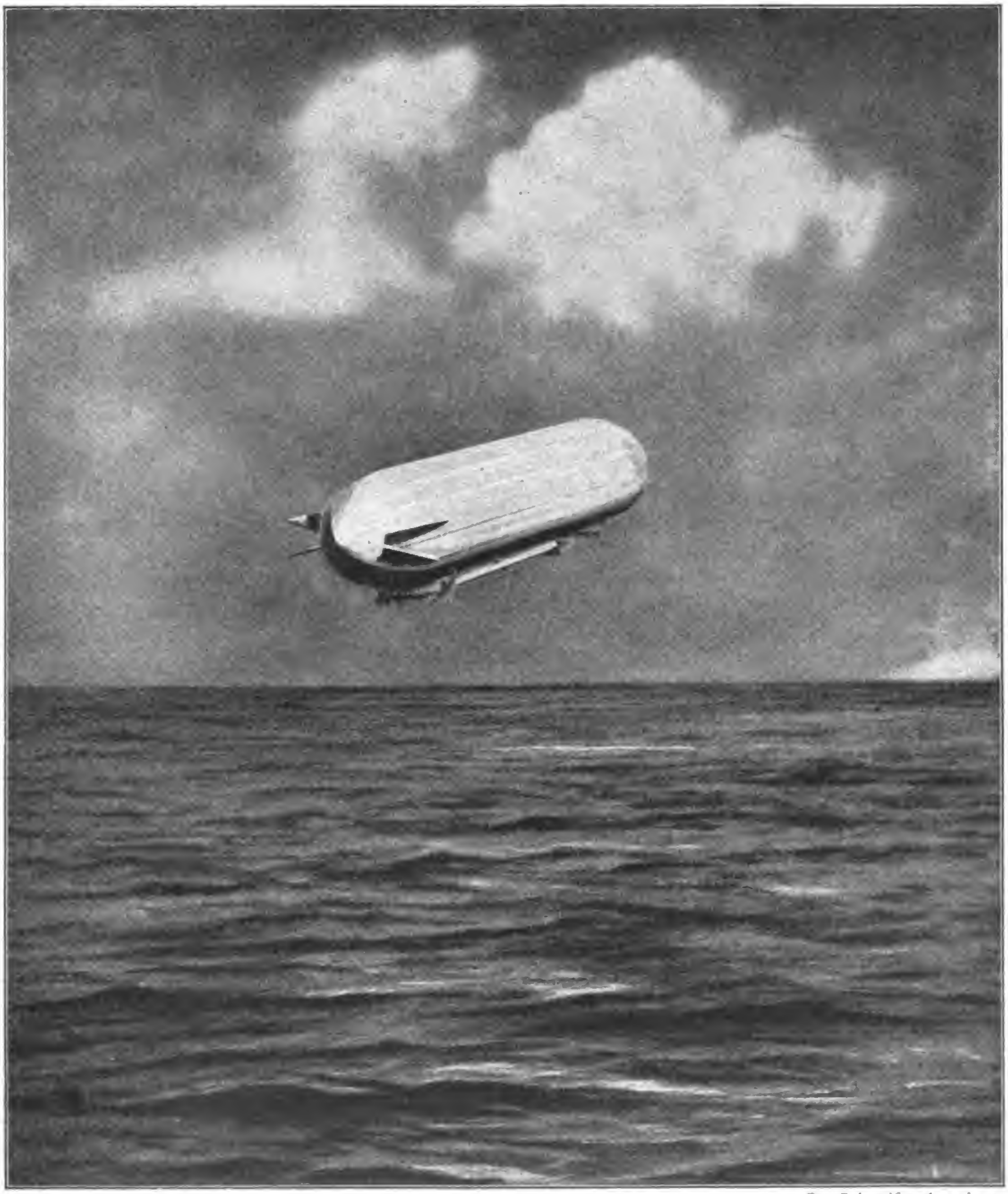
But Count Zeppelin, despite his numerous accidents, was on the right track, aeronautically speaking. He realized that only the dirigible could in time be made the carrier of vast cargoes and vast numbers of passengers over long distances. He realized that in great dirigibles there would be safety, and he was ever striving to make his machines larger and still larger.

WHAT THE ZEPPELINS ACCOMPLISHED

For bombing purposes, the Zeppelins were fairly successful at first; but as the anti-aircraft equipment and personnel of the French and the British became more and more perfected, the Zeppelin raids became proportionately more expensive. The last Zeppelin raid on London during the latter part of 1917 cost the Germans five Zeppelins—obviously too high a price for the mere blasting of a few houses in London. And from that time onward the Germans concentrated their bombing efforts on huge fleets of large airplanes.

But when it came to naval scouting, the Zeppelin proved to be the ideal means of reconnaissance. Germany was able to use her Zeppelins with marked success in many diverse functions, and little was said about it during the war. It is noteworthy, however, that one Zeppelin was decorated with the Iron Cross "for coöperation with submarines during a successful attack on three British armored cruisers." Several Zeppelins have also been known to coöperate with German submarines for enforcing the so-called submarine blockade, by stopping and occasionally sinking such merchantment as they could not bring to a German port. Other Zeppelins were engaged in patrolling the German shores from Holland to Denmark and from Denmark to Russia; still others played an all-important rôle as fast scouts for such portions of the German fleet as ventured beyond the range of Heligoland's coast batteries. Their participation in the raid on Lowestoft and in the great Jutland battle even raises the question whether the twofold slipping of the British blockade by the German commerce raider *Moewe* may not be attributed to intelligent coöperation between her skipper and one or more Zeppelins. The high speed of these airships, and their faculty to send as well as to receive wireless messages over long ranges, make this assumption appear quite plausible.

German official reports always seemed to omit purposely all references to this sort of work done by Zeppelins, while particular emphasis was laid on the destruction achieved by Zeppelin raids against the British Isles. From a military viewpoint the Zeppelin raids on England were of comparatively small importance, though some of them may have served the purpose of a "reconnaissance in force," either for ascertaining the whereabouts of Sir John Jellicoe's Grand Fleet or else for reconnoitering the location of English coast defense works. If such really was the purpose, then the dropping of bombs was successful from the German point of view, as it



© Scientific American.

One of the Earlier Zeppelins Flying Over the Water

These early Zeppelins were pencil-shaped, instead of stream-lined. As a result they offered far greater resistance to the air and made a relatively slow speed for a given horsepower. Later the Germans stream-lined their Zeppelins, and placed the engines in separate bodies, suspended from the big envelope.

forced the British to disclose the location of their batteries by firing on the air raiders.

There was still another important function which Zeppelins may have fulfilled for the German Fleet, namely, gun-spotting. During the Gallipoli campaign the *Queen Elizabeth* repeatedly fired across the peninsula, hitting targets invisible to her gunners, the correct range being given by seaplanes through wireless.

But seaplanes cannot yet—on account of their short radius of action—cruise with a fleet out to sea; it is true that they may be carried on mother ships, but in this case their movements will be dependent on their floating bases, whereas Zeppelins may cover 1,000 nautical miles independently. The advantage then lies obviously with the airship, continues Ladislas d'Orcy, writing in the *Scientific American,* the more so as the latter might spot the guns while remaining stationary and send, as well as receive, wireless messages.

It did not take the British long to discover the value of huge rigid dirigibles, as well as small dirigibles which have come to be known as "blimps."

The Zeppelin type, which is practically the forerunner of the huge British dirigibles employed during the war, has the following characteristics:

THE HULL

David Schwartz, the Hungarian engineer, actually fathered the rigid airship, for, having built two such craft as far back as 1893 and 1895, he first employed the method of building up the hull frame of longitudinal girders and crossrings. This system has victoriously withstood the test of time; it is not only used up to date in the Zeppelin, but was also employed in the British Vickers and the French Spiess airships, and even the Schuette-Lanz design which originally substituted for the longitudinal girders a spiral cross-lattice work of laminated wood, promptly reverted to the older type in the second airship.

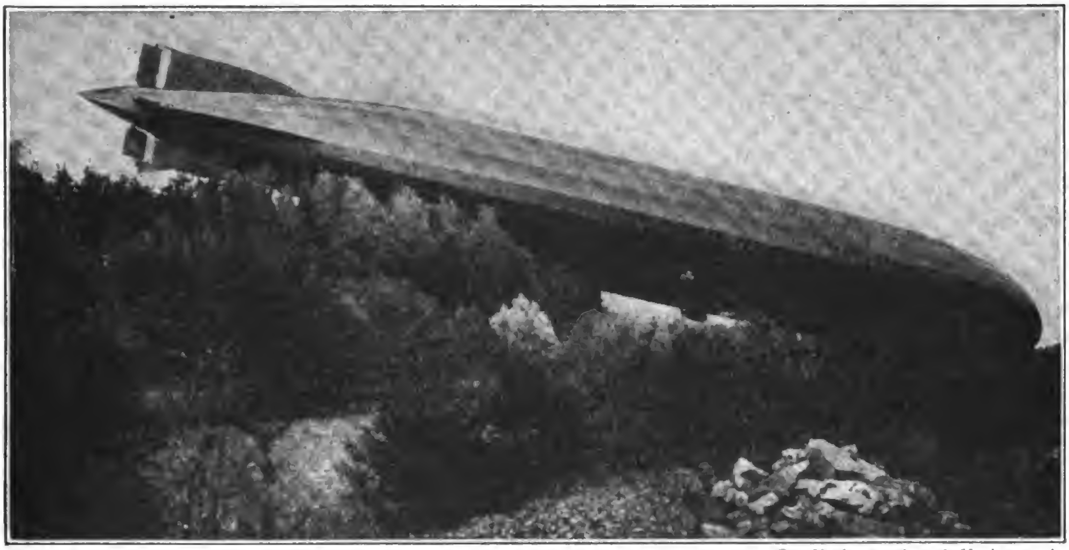
The material used in the frame of the early rigid airships was practically pure aluminum which Schwartz employed in the form of tubes and Count Zeppelin in the form of lattice girders; the great brittleness and consequent unfitness of this metal for airship construction revealed itself when one of Schwartz's airships burst upon being inflated while the other one broke up upon landing, not to speak of the countless collapses the early Zeppelins suffered. Since the aluminum industry has produced zinc-aluminum alloys whose tensile strength approaches that of cold rolled steel for but one-third the latter's weight, rigid airship hulls have become less apt to break up on coming somewhat roughly in contact with the ground; still this danger permanently exists in a lesser degree and it appears that the only way to overcome it would consist in adopting the wire bound wooden trelliswork of Schuette-Lanz pattern whose springiness constitutes its greatest asset, although its unit weight is greater than that of a Zeppelin hull.

One of the most important items of an airship is the shape of its hull, for this determines the amount of air resistance that must be overcome, the most favorable shape being obviously the one which affords the greatest power economy. In Schwartz's days it was the projectile that was supposed to meet the least resistance through the air; consequently the Schwartz airships had a cylindrical form with a pointed bow and a rounded off stern, and were only four diameters long. Laboratory research work has since revealed that the most efficient airship hull is one six diameters long with the master diameter at about 40 per cent. of the length from the nose, the general shape being elliptical and the nose somewhat blunter than the stern. This hull shape is now being used by all airship builders, including the Zeppelin organization, which long adhered to the characteristic pencil shape of nine to ten diameters length, so that modern ideas may be found on the latest models in the blunt bow and conical stern which have taken the place of the formerly symmetrical arched points. The most plausible explanation for this seemingly uncalled for conservatism seems to be the fact that standardization of parts is infinitely more simple for a hull which is straight sided over three-quarters of its length, where its crossrings are consequently of the same diameter, than for an irregular ellipsoidal shape. And since all the girder rails and web pieces of a Zeppelin are punch pressed the importance of having a small number of sizes becomes self-evident. Another reason why Germany

seemed unwilling of giving up the classical pencil shape of Zeppelins is found in the size of her airship sheds which were built large enough to take care of future increases in size for a given ratio of length to beam only, so that by suddenly decreasing the fineness ratio of the latest Zeppelins to 6:1 none of Germany's pre-war sheds would afford a berth of sufficient width for these leviathans. In this country where no such conditions prevail, airship designers could well afford to avoid drawing their inspiration exclusively from German sources, for it seems that American ingenuity coupled with a proper training *both* in engineering and aerodynamics should ultimately produce something better than the Zeppelin.

It is interesting to note that on the latest known type of these airships the gangway which formerly was contained in a V-shaped keel protruding from the hull has now been placed within the latter and is in the form of an inverted V with a flat bottom; obviously a corresponding sector of the drum-shaped gas cells is cut away. Gas leakage is taken care of by ventilating shafts leading to the roof. The gangway runs through the greater length of the bottom and connects the cars as well as a gun emplacement on the stern above the elevators; the frontal gun emplacement on the roof is reached through a stairway shaft.

The skin of the hull is, as on all modern airships, a specially treated fabric whose elasticity coefficient makes it more desirable than the aluminum sheeting the late Schwartz used on his vessels. This metal skin which Schwartz believed would prove more impervious to gas than a fabric envelope proved very leaky because the torsion of the hull—all airships sag to a certain extent—caused the plates to spring.



Zeppelin *L-49* Brought Down by the French

It was shot down on its return from a raid over London. The photograph shows the Zeppelin lying on a hillside near Bourbon.

CARS AND PROPELLING MECHANISM

The difficulty of connecting the propelling apparatus to the hull can be said to increase with the airship's size. Generally speaking, the necessity of evenly distributing the masses carried makes airship designers split up the power plant into several units mounted on several cars, an arrangement which advantageously limits the size of propellers and also reduces the chance that an engine breakdown will put the whole power plant out of commission. This explains why the characteristic

two-car side-drive of the Zeppelin has given way on the latest models to four cars arranged crosswise, a system which had previously been tried on the Schuette-Lanz airships. In this case only the bow and stern cars are mounted co-axially, the two other cars being hung side by side from the middle of the hull. Each car houses one engine which drives through a clutch transmission a propeller mounted aft of the car; the stern car, however, is fitted with two more engines driving in the old-fashioned way two side propellers through bevel gears. Thanks to this clever arrangement all the propellers work in "pure air," for the only two which are co-axial are so far apart that no interference can result therefrom. The cars are streamlined and, on account of the cold met at great altitudes, totally enclosed; they are built up of lattice girders similar to those used in the framework and are covered with corrugated sheet metal.

It is remarkable how closely the design of airship control surfaces has followed the evolution of the corresponding organs of airplanes. The complicated multiplane rudders and elevators which were an outstanding feature of early Zeppelins have now been displaced by symmetrical monoplane surfaces arranged crosswise, the advantage derived thereby consisting in that one large control surface is not only much more effective, but can also be made infinitely stronger than several small ones. The symmetry of the control organs is of self-evident reason if one keeps in mind the symmetrical cross-section of the hull which is a twenty-five-sided polygon, the gangway-keel with its corresponding side resistance having been discarded. No swiveling or fixed propellers for direct lift appear to be used on the latest Zeppelins which several reports credited them with; still this feature, which is no novelty since it has successfully been used on various French and British airships, seems well worth closer investigation.

ACCOMMODATION AND ARMAMENT

The "brains" of a modern Zeppelin are centered in the bow-car. This has three compartments, the foremost one being fitted as the navigation room and commander's cabin, next to which comes a small wireless room, the rear compartment being the engine-room. The commander's cabin is fitted, in addition to the customary navigation instruments, gas pressure gauges, engine revolution counters and engine room telegraphs, with a switchboard which controls the electro-magnetic bomb release devices. The bombs are carried amidships, so as not to upset the longitudinal equilibrium when they are released, and are hooked to two parallel girders, each of which carries thirty bombs, on either side of the gangway. The release of the bombs is effected by a series of levers which are set working by an electric current but can also be operated by hand.

The defensive armament of the super-Zeppelins consists of nine machine guns, some of which are said to be of larger caliber than the ordinary small arms ammunition. Three of these are mounted on the roof, two near the bow, side by side, and one on the stern; the remainder are distributed among the cars, firing broadsides.

It has been variously reported that the latest Zeppelins are from 230 to 240 meters (755 to 787 feet) long and are fitted with seven or even eight engines, developing a total of 1,500 to 2,000 horsepower. The existence of an observation car which could be lowered from the airship by means of a winch was at last definitely ascertained, for one such car was picked up in East Anglia after a Zeppelin raid. The car is of streamline shape, about fourteen feet long and five feet high, and is fitted with a cruciform tail which serves to keep it head-on to the relative wind. Owing to its very small size the car could be lowered a few thousand feet without fear of detection from the ground while the airship remains hidden in the clouds; the observer is thus given excellent opportunity for reconnoitering things below and transmitting the result by telephone to the chart room.

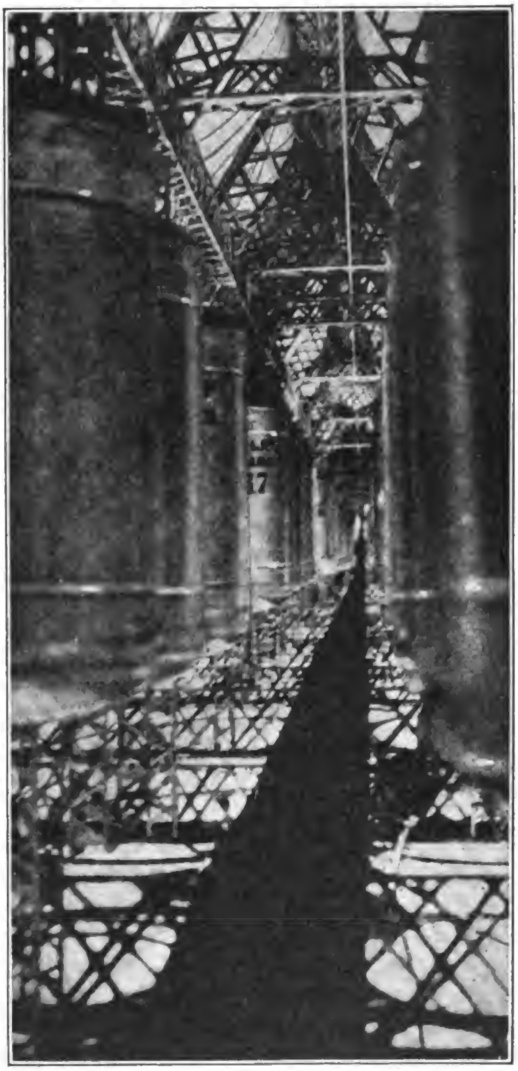
HOW ALL ZEPPELIN SECRETS WERE BETRAYED TO THE ALLIES

Had the German commander of the Zeppelin *L-49* been more successful in aiming the shot with which he intended to destroy his craft after a forced landing on French soil following an engagement with a French bat-

tleplane, he would have reduced the aerial leviathan to a mass of twisted aluminum and shapeless lumps of equipment. But his inflammatory bullet missed a balloon unit by a few feet, and before he could fire again a retired French soldier "covered" him with a shotgun. In this manner the *L-49* fell into the hands of the French and other Allied aeronautical experts practically intact; and thus all the secrets of the super-Zeppelins were made available for the first time. This happened in the latter part of 1917.

Reports of that time stated that the *L-49* was evidently a recent type of Zeppelin, probably one of the many turned out in 1916, and intended for scouting out at sea and for raiding purposes. Much credit is due the designers for the care and the skill displayed in the arrangement of the craft as a whole, and in the treatment of minor details. But the construction in general impresses one with a sense of hasty workmanship, for there is much of the makeshift order in evidence. In fact, this bears out the rumor that the Germans for some time before December, 1917, had reduced the Zeppelin to a standardized manufacturing proposition, and that many of the aluminum and other metal parts were being stamped out in large numbers at various plants and assembled at the airship factory proper. However that may be, the tendency toward eliminating the finish on everything where finish was not essential appeared then to be spreading in Germany; in the enemy's airplanes, for instance, the finish had been noticeably declining in captured models, and the comfort of the airmen appeared to be the least consideration of the designers and the constructors. So, with the Zeppelins, it is more than likely that finish and the comfort of the crew were being sacrificed for fighting efficiency, which, in the raider type, meant shaving off every pound of weight possible in order to increase the bomb-carrying capacity.

Like most other Zeppelins, the *L-49* carried a powerful wireless set. Indeed, the wireless room was ostensibly one exception to the rule of makeshift construction, and in a general way it was strongly suggestive of the wireless room of an ocean liner. French officers who examined the wireless apparatus stated that no new principles were involved, although there were many novel features of much interest. And despite the fact that the wireless apparatus was damaged by hammer blows before being abandoned by the operator, it was held that Allied experts would be able to reconstruct it without undue difficulty.



© *Underwood and Underwood.*

Interior of Dirigible *R-34*

Showing the gas chamber inside the huge bag. The photograph was taken while the dirigible was flying over the Atlantic.

The super-Zeppelin was commanded from an enclosed bridge, just forward of the wireless room. In order to protect the occupants from the cold and wind, the bridge was provided with a three-ply wind-shield and a

heavy fiber mat. All the controls were at hand, so that the giant airship, like its counterpart on the high seas, could be guided from the bridge. For operating the vertical rudder and the elevating planes, handwheels were provided, much after the fashion of those used on motor boats. An elaborate chart table also formed part of the bridge equipment, as did a control board containing thirty-eight red and white buttons, each of which took care of the expansion or the contraction of one of the balloons. Light stools made of three-ply thin wood were used in the navigating room by the crew.

The power plant of the *L-49* consisted of five separate units, the largest of which was just aft of the wireless room. Running the full length of the envelope was a narrow gangway which permitted the crew to walk from one part of the aerial greyhound to another, giving ready access to any one of the engine rooms. At one point there was a well or tube, formed of balloon fabric, enclosing a light aluminum ladder which led to a small gun platform on top of the envelope. This platform mounted two machine guns which could be brought to bear on hostile battleplanes attacking the airship from above. The other power units were housed in bullet-like gondolas or cars which were suspended below the balloon proper, and which were reached from the gangway by climbing down eight-foot ladders.

LIKE SO MANY PEAS IN A POD

The envelope of the Zeppelin contained nineteen balloons of gold-beater's skin, with ballonets inserted in each one, so as to form an integral member. These ballonets were an essential part of each balloon unit, and served to take care of the expansion and the contraction of the hydrogen gas, thus maintaining the proper conditions in each balloon regardless of the altitude at which the airship was traveling, the temperature, or any other vital factor. The ballonet valves were under the control of the navigator on the bridge, as stated above.

Also contained in the envelope were the water ballast tanks, so arranged as to distribute the weight along the entire length of the craft. These tanks were of canvas, and each had a capacity of about 200 quarts. Any desired tank could be drained of its contents from the bridge, and the buoyancy of the Zeppelin could be delicately and readily controlled.

Fuel for the engines was carried in sixteen tanks of substantial construction, so piped that any one of the tanks could be used to feed one engine or all the engines. The German constructors had evidently taken every precaution to safeguard their fuel storage and distributing system in order to reduce to a minimum the fire hazard.

It is known that a parachute was found in one of the engine rooms, suggesting that parachutes were perhaps used by the crew to escape from a doomed Zeppelin. Hammocks were found in considerable number, indicating that the crew rested after the fashion of sailors on board warships. But the chances are that the better part of the instruments and miscellaneous equipment was thrown overboard to lighten the craft when the crew was bending every effort to escape a French battleplane, just before landing.

All in all, the *L-49* was an interesting craft. Still, after the many wild rumors which continually emanated from Swiss sources concerning the wonderful super-Zeppelins being tried out over Lake Constance, the secrets betrayed by the present type were somewhat disappointing. There was no evidence of marvelous bomb-dropping apparatus, tremendous speed, all-powerful armament, gigantic proportions, mist-producing machinery for hiding from enemies, or non-inflammable gas in place of hydrogen. Again we are led to believe that these things existed mainly in the minds of the Teuton *camoufleurs,* whose chief rôle during the war seemed to be to inspire fear among the civilian population of enemy countries.

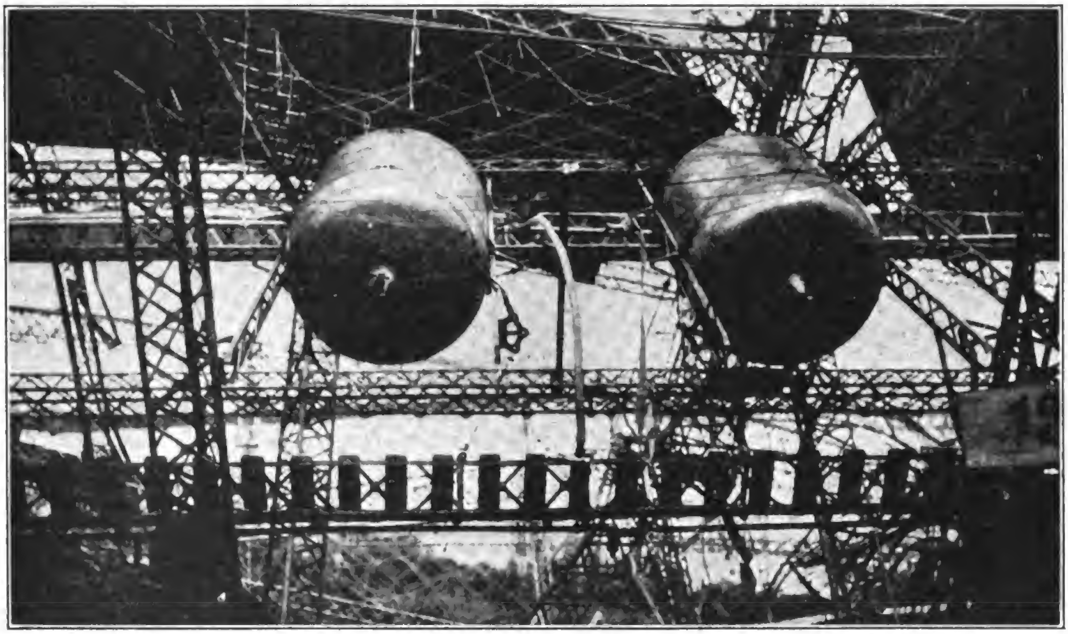
FURTHER DETAILS OF THE ILL-FATED ZEPPELIN

The framework of the present super-Zeppelin contains three distinct varieties of aluminum, namely, pure aluminum, aluminum alloyed with zine, and duralumin. The last-mentioned variety is a well-known alloy of copper, manganese, and about 93 per cent. aluminum; and although its weight is about

equal to that of pure aluminum, it has three times the tensile strength. The framework of the *L-49* has been estimated at 600 feet in length, seventy-five feet extreme diameter, and with a capacity of 55,000 cubic meters.

Along the bottom of the huge bag runs a triangular-shaped passageway walled in by a light metal framework, with its apex at the top. The gas bags fold over the triangular framework of this passageway, so that any one passing through it is virtually surrounded by the gas bags on two sides and the aluminum framework and outer covering, surmounted by the footway, underneath. This gangway or "cat-walk" forms the keel of the big cigar-shaped bag, and serves to connect the various power plants and gun platform of the Zeppelin with the forward or commander's quarters. The passageway is usually quite dark; but the footway is provided with a hand rail, while at intervals along the framework members small disks of radium paint serve clearly to mark the way. Indeed, control dials and sign boards in the main passageway and the branch passageways are provided with radium dials and characters, making the use of dangerous lights unnecessary.

Aside from affording a means of communication between various parts of the aerial leviathan, the "cat-walk" serves as sleeping quarters and as storage space. The sleeping quarters are represented by a number of hammocks supported a few inches above the outer fabric cover, to one side of the pine board-walk. Fuel tanks and ballast tanks are suspended from the framework on either side of the board-walk, and it appears that the bombs are also supported in the passageway. The fuel reservoirs are aluminum cylinders of 300-liter capacity, and are suspended in groups of two or three. Means are provided for readily releasing these tanks through trap doors in the bottom of the passageway, in the event that every pound of weight which can be spared has to be dropped to lighten the Zeppelin so as to ascend rapidly. Tubes connect the fuel tanks with the engines in the nacelles below, and aside from the main fuel tanks a number of others, not piped to the engines, are kept on hand as an emergency supply.



© *Underwood and Underwood.*

Two of the Fuel Tanks of the Zeppelin *L-49*

The ballast reservoirs which replace the former sand bags are made of waterproof cloth and provided with an aluminum spout at the bottom. Each ballast unit has a ca-

pacity of 1,000 liters of alcoholized water, and it is of interest to note here that the freezing of this liquid ballast prevented the *L-49* from making for the higher altitudes to escape hostile battleplanes, after the gas supply had become seriously depleted through long flight. The ballast reservoirs are suspended from the framework of the "cat-walk" by means of steel cables.

A SURPLUS OF ENGINES TO INSURE SAFETY

Four nacelles house the engines—two laterally suspended near the center of the airship, and one near each end. The rear nacelle carries two motors, one of which is an emergency unit. Each engine is rated at 240 horsepower, making a total of 1,200 horsepower for the airship. Each propeller measures five meters in diameter. The nacelles, which are more or less egg-shaped, are occupied mostly by the engines, and it is reported that little space is left for the tenders; in truth, the crew in this respect are working under conditions no more enviable than sailors aboard a German U-boat.

The front nacelle is divided into two compartments, the forward or commander's quarters provided with sliding plate glass windows in front, and the rear or engine room. All the controls of the huge airship are centered in the commander's quarters. Among the instruments are a compass, the steering wheel, the bomb-sighting apparatus at the right, with a tank of compressed oxygen just below, and the commander's parachute rolled up at the left. By means of a keyboard the cargo of bombs can be dropped one by one, while a battery of electric lamps shows which bombs have been released. A signal telegraph permits of instant communication with the various engine rooms.

That the present super-Zeppelin is a vast improvement over its predecessors is evident from a study of its lifting power, which is said to be sixty metric tons. This is distributed about as follows: Framework, thirty tons; two middle nacelles, two tons; two end nacelles, four tons; fuel for twenty-four-hour flight, seven tons; equipment and accessories, one ton; nineteen passengers, one and one-half tons; bombs, two tons, making a total of forty-seven and one-half tons. This leaves a margin of twelve tons of lifting power, which is ample for all navigating conditions.

The crew comprises nineteen men and two officers, who are posted as follows: two in each of the middle nacelles, three in the rear nacelle which contains two engines, and four in the front nacelle. The remaining members are placed in the passageway or "cat-walk," where they take care of the ballast tanks or snatch a few hours' sleep until called upon to relieve other men. The crew of such a craft, it goes without saying, must be composed of exceptional men—men who can withstand extreme cold, lack of oxygen, and constant nervous strain.

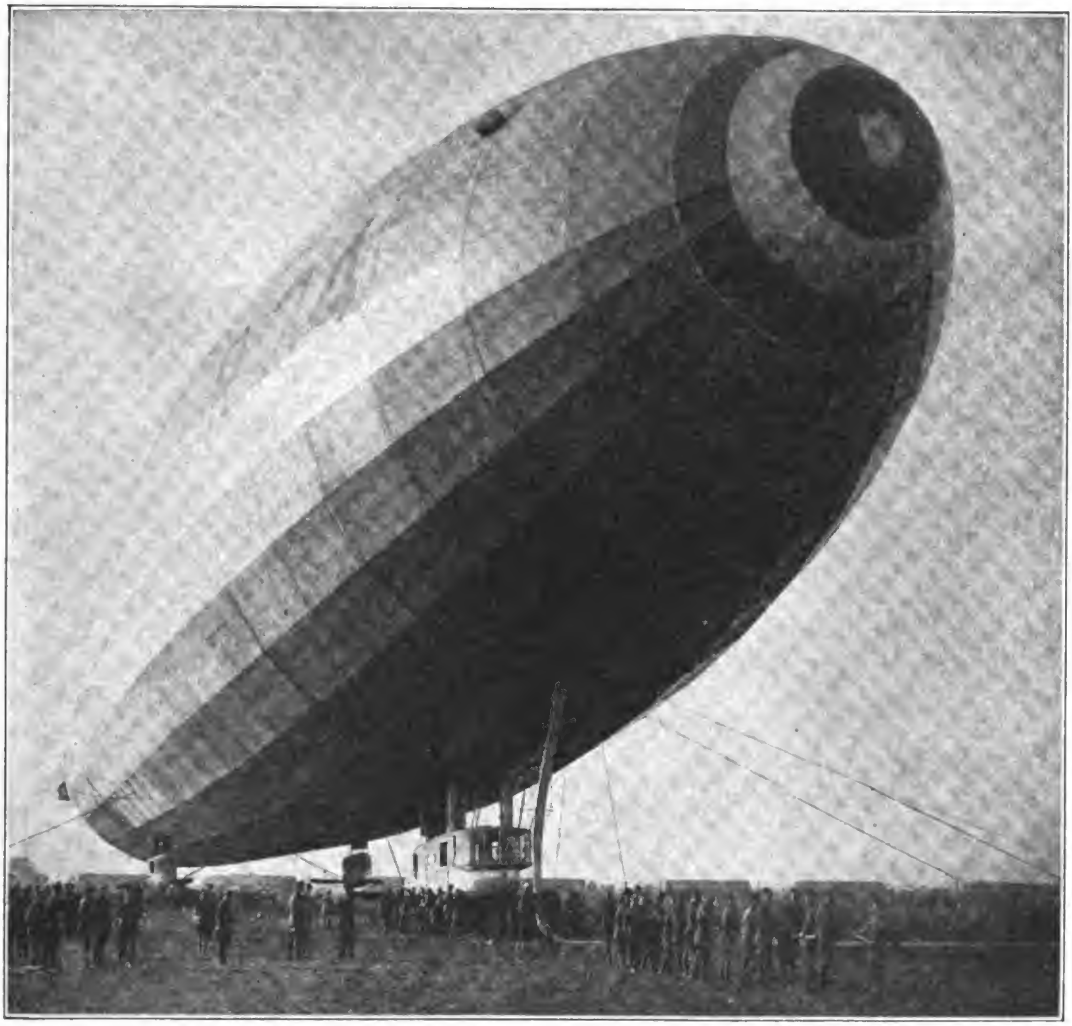
THE ARCH IMITATOR IMITATED

Once the British made up their minds that their fleet and land forces required Zeppelin type airships both for returning each visit of raiding Zeppelins and for naval reconnaissance, the leading British aeronautical engineers set to work on the problem. Several small rigid balloons were developed, and grown bolder by their successes the British essayed a true Zeppelin type of dirigible.

The result was the *R-33* and *R-34,* twin dirigibles, which were launched too late to be of use against the Germans. In fairness to the late foe, be it admitted here that these two British airships are very close copies of the Zeppelin. In fact, the description already given of the Zeppelin *L-49* applies more or less to the British *R-34* which made the trans-Atlantic crossing, at least so far as general details are concerned.

In connection with lighter-than-air craft, the United States has always lagged behind and is still behind, but we made a late start. For example, in the care of free balloons and the early dirigibles, the experimental work and the pioneering were confined almost entirely to France. The French two generations ago had worked out the complete theory of design and operation for these types. They knew all about them before there were gasoline engines to put into the airships to make flight at all useful. The Germans started with airship work about 1895; the Italians somewhat later; the English, probably, made no serious effort until about 1911 and 1912. The United States began in earnest in 1917.

Following the example of our English friends, who have quite caught up from the time they have been at it, we ought to be able to catch up very shortly, if Congress will vote the necessary funds.



© Underwood and Underwood.

Putting Gas in the *R-34* at Mineola

The dirigible is shown at Roosevelt field. Note the huge tube through which gas is being fed into the airship.

The first serious work with airships in the United States was done in 1917, when the Navy Department arranged for the construction of sixteen small ships. They have been described as "blimps." According to Commander J. C. Hunsaker's address before the Society of Automotive Engineers, these ships were not based on any foreign type. They were designed before the United States entered the war from a picture on the back of a postcard that was smuggled out of England, and from an account by a returned traveler who had seen something in England that he tried to describe. The United States Navy, according to this officer, had the information that the English were working on a certain small airship for a submarine scout and that the type was useful. We then started with the same general problem, and as very fre-

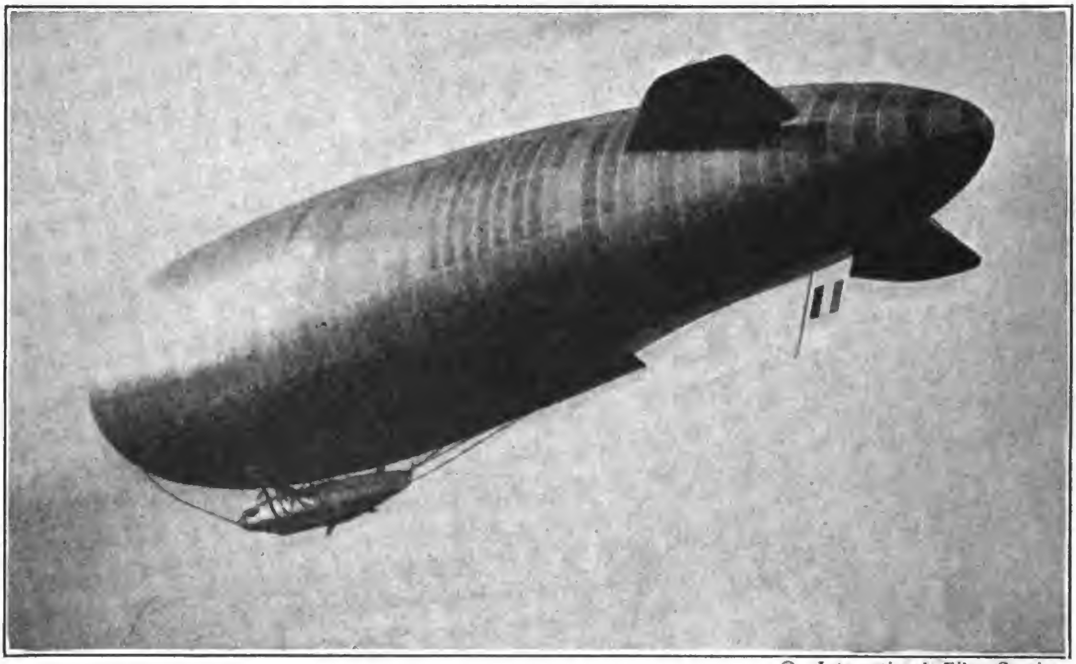
quently happens, we came out with about the same result.

We built sixteen of these small airships, the principal characteristics of which were about as follows:

Volume in cubic feet......	84,000
Length (over all) feet....	164
Type of engine...........	Curtiss
Size of engine, horsepower	100
Speed, miles per hour......	45
Range at full speed in miles	500

DIRIGIBLES THAT FOUGHT SUBMARINES

These ships have done regular submarine patrol work along the Atlantic coastal waters throughout our period in the war, and have acted as convoys for whole fleets of merchant ships; they have really been useful for that limited function. They cannot go very far to sea because they have only one engine. We had one case where a few lads in one of them got caught out at sea and in a helpless con-



An American Dirigible

This particular type is 162 feet long, and equipped with two 150 horsepower motors which give it a speed of 65 miles per hour.

dition drifted for two or three days and came down at Halifax. Their being saved was more good luck than good management, so we decided that we wanted two engines, and have brought out our second type with twin Hispano-Suiza engines. This is nearly twice the size of the first model and the speed was pushed up above sixty miles an hour, the radius being about the same. The ships with the twin engines are fairly new, but the first one of the series has flown from Akron to Washington, then to Rockaway, and later down from Rockaway to Key West. The longest flight was, according to Commander

They are not remarkable for any great performance, but they trained about 150 pilots for us in the time we had them working, and did about 4,000 hours of patrolling, covering 140,000 miles.

Until the time of writing, which is July, 1919, there have been no lives lost as a result of accidents to these ships, although almost everything that could has happened to them. That is an excellent record, one must admit. We claim, of course, that the principal reason for the fine showing is that the ships were well built to begin with, in addition to being well handled.

Hunsaker, thirty hours. One of these ships, the *C-5*, flew from Montauk Point, Long Island, N. Y., to St. Johns, Newfoundland, in order to essay the trans-Atlantic flight. In a violent windstorm, however, the ship broke loose from her moorings and was blown out to sea.

These non-rigid airships can be built pretty rapidly, and as we know from our own experience, they are fairly safe. They are used principally for coast patrol and convoy work. Their duties are supplemental to the rapid and intensive surveillance of coastal waters by seaplanes.

We always want to be sure that we do not get into any argument with our heavier-than-air friends, Commander Hunsaker goes on to say. There should be no argument. Just as men will argue as to whether the mountains are better than the seashore, men will argue as to dirigibles and seaplanes. But after all is said and done, it all depends upon what you want them for.

The seaplanes watch the area within 100 miles of the coast and zigzag back and forth over assigned sectors during daylight. The small airships proceed further out to sea beyond the range of seaplane patrols, to watch for submarines and enemy mine fields, but principally to accompany convoys of merchantmen. An airship can loaf along for a day or two with the convoy and not leave it to return to port until it is well out in the open sea and comparatively safe. This function of convoying ships out from our coastal waters is pretty well accomplished by our present types, but of course we shall keep on improving them. However, the amount of improvement that we can get is not very great. When we come to consider the fleet requirements for a strategic scout, we must have an airship with an endurance in the thousands rather than hundreds of miles. We have then got to think of the German Zeppelin. The Germans have developed just such a weapon, have taught us how it should be used, and how it ought not to be used, and have very obligingly presented specimens of their work to the Allies from time to time, so that there are no longer any secrets about it.

OUR SKY SAUSAGES

The Contribution of the Captive Balloon Toward *Strafing* the Hun

ALMOST anywhere along the Western front one could see them—if not ours, then French or British. They floated lazily at various altitudes, their cables, netting and basket supports invisible, gray or gold against the sky. If floating low, and seen from the direction to which the wind is blowing, they presented a quite absurd likeness to a huge elephant, the vanes, two horizontal and one vertical, looking for all the world like huge ears and a curled-up trunk.

They are distinctly a development of this war. The captive balloon was used in many previous wars, but always as a spherical bag. And the spherical balloon, captive, is about the most unmanageable air brute conceivable. On a clear calm day it is as serviceable as the best of the "kahkos" (the "doughboy" translation of Captain Caquout's name), but in a wind, a spherical balloon is a merciless tosser about of instrument and observer, and is not capable of much altitude anyway, because of the immense surface which it offers to the moving air.

WHAT IS A "KAHKO?"

The "kahko," continues C. H. Claudy, writing in the *Scientific American*, is long and slender and possesses the three vanes which hold it steadily in the air, even in high winds. These vanes are filled by the wind—they are but long curled pockets in the fabric and the harder blows the wind, the tighter do they fill and the stiffer do they hold. When the balloon is hauled down for storage over night, in balloon house or field shelter, the vanes droop and die, and are thus not at all in the way or liable to damage.

Never before has gunnery achieved the accuracy which this war has demanded of its artillery. Never before have the demands from artillery for observation been so exacting. Always there has been a correction in the range and deviation formula by which heavy guns are pointed, this correction dealing with the wind. But never before has it been so important to know just what correction to apply. This war has demanded accurate knowledge of wind direction and velocity not only at the surface but at various heights above the surface, for never before, certainly not for America, has big-gun ammunition been hauled so far before firing, thus becoming exceptionally valuable.

So the captive balloon has had as one of its principal duties the carrying of an observer and observing instruments into the upper air, by means of which the wind direction and the velocity can be accurately obtained.

Wind velocity is obtained of course from the familiar anemometer. Wind direction is obtained by the use of a compass and an observation of the balloon itself, which always points squarely into the wind, its vanes at the point of the compass to which the wind is blowing. And while it is true that the captive balloon cannot by any means reach such heights as a shell, it is equally true that observations of wind at various altitudes will frequently tell the whole story of wind velocities at altitudes far above those which can be reached with the instruments.

The duty of the observer in the captive balloon only begins, however, with his meteorological observations. He is able to do photographic work of peculiar value in making maps, since he can make two or more pictures at altitudes that are known with extreme accuracy. His position above the terrain is also known with extreme accuracy and even the non-mathematician can see that having two photographs at different altitudes in a vertical line, a known distance apart and absolutely located above the terrain, it is a mere matter of calculation to construct a map accurately to scale.

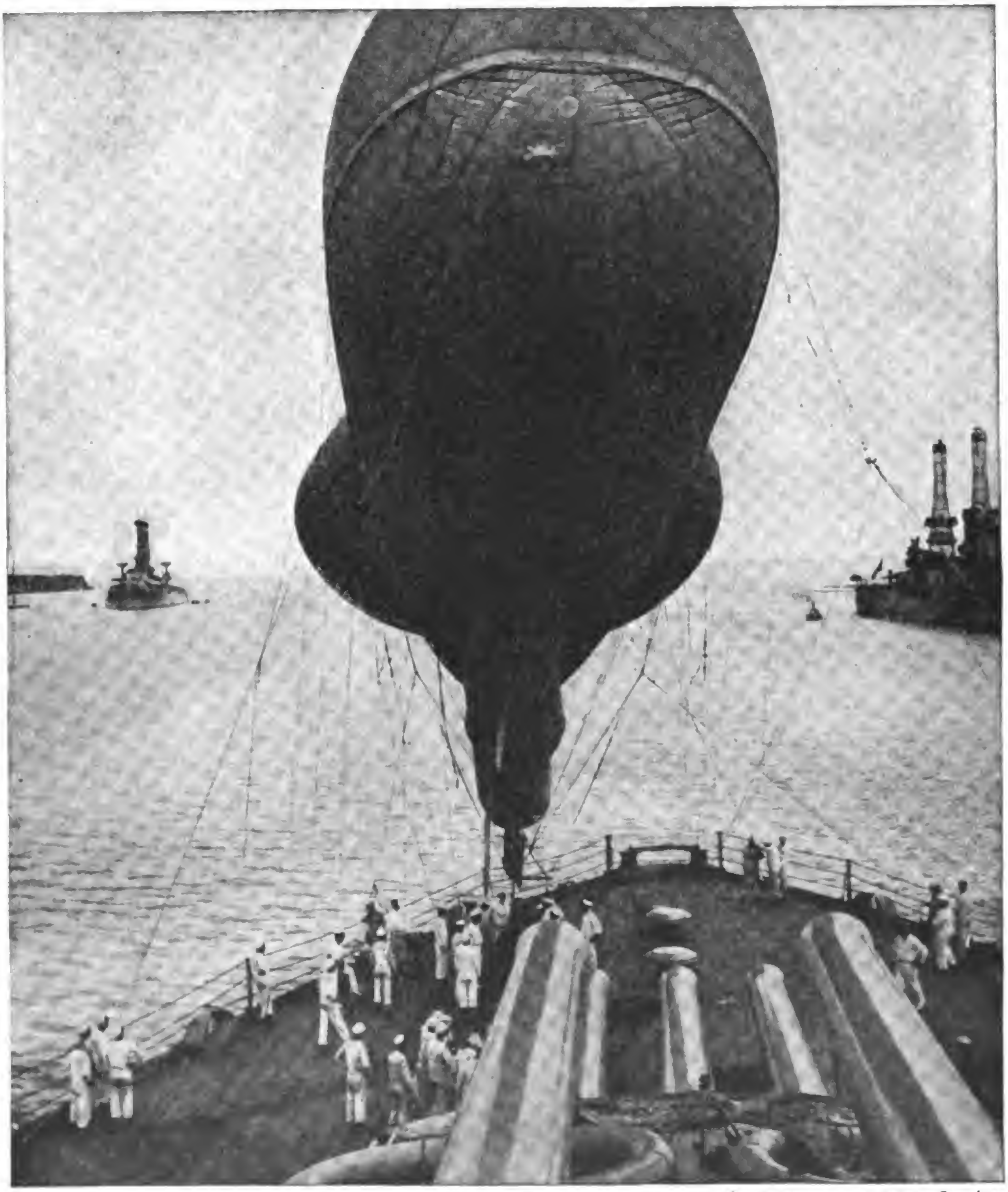
The captive balloonist has also much to do with observation of artillery fire. He is in a much better position to watch than the airplane observer, because he is unhampered by continual motion. True, he cannot get over or near the target, as can the mobile plane, but on the other hand, he can use glasses with the same ease he might upon *terra firma,* and complete observations at his leisure which the plane observer must make in a moment. At the extreme ranges of twenty miles or more, balloon observation is of little use. But it is said that for big gun fire at ranges as high as fifteen thousand meters on a good day balloon observation will reach an accuracy not less than ten meters. That means that at something less than fifteen miles an aerial observer can judge within thirty feet where a shot struck. Such observations are more likely to be accurate for deviation than for range, of course, but are vital for all that.

Another advantage which the balloonist has over the airplane is that of constant telephonic communication. Of course, the wireless telephone has been developed surprisingly, and is in use in airplanes. But at its best it is a limited power, and requires a muffling of the observer in a headpiece to keep out motor sound, which by no means adds to the ease of making observation. The balloon observer is in constant wire telephone communication with those below. His telephone wire is wound up or reeled out on a separate reel as his cable is lengthened or shortened, and he can both send and receive his messages with the same ease as does a business man at his desk.

ACTIVITIES OF A KITE BALLOON COMPANY

The mechanics of flying a captive balloon includes the filling of the bag, the management of winch, and the storage and care of the bag when resting on the earth. Simple as these things appear, they have been the source of a great deal of study and have resulted in the development of a balloon technique which produces the maximum of results in the minimum of time. A balloon company will include some two hundred men, and at least three officers, more of the latter often being necessary where continuous observation is required or where the hazards of the service are such as to make constant relief from the strain of aerial duty a necessity.

In any captive balloon work at least two and often three are always on duty—one or two aloft, charged with making observations,



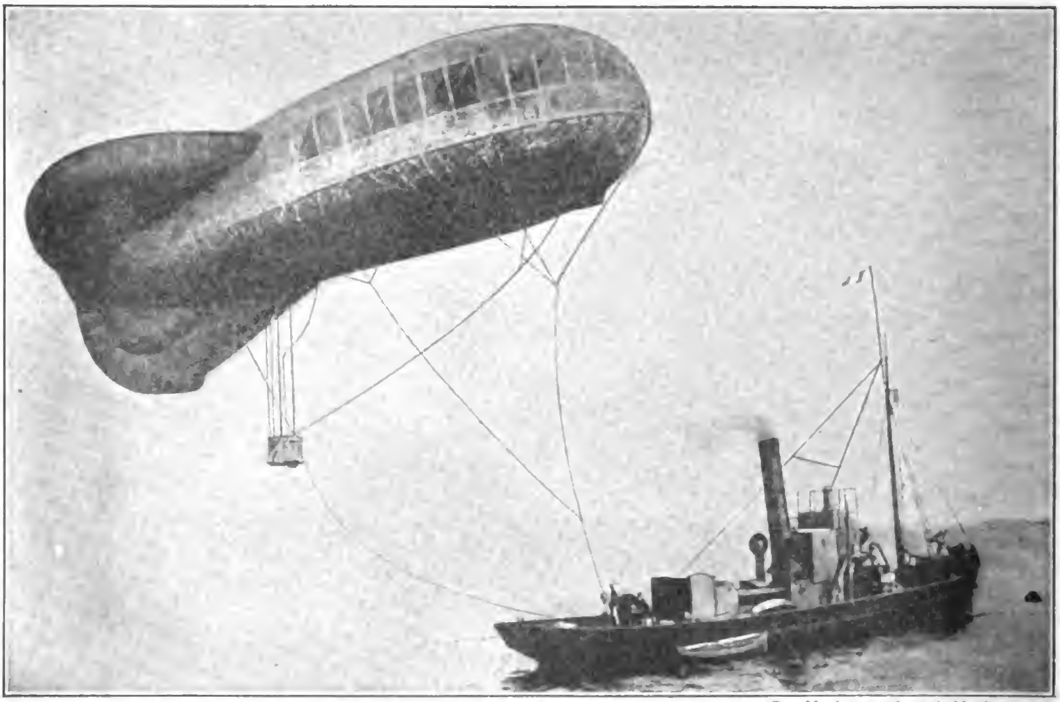
© International Film Service.

One of Our Kite Balloons Operating from the Deck of a Battleship

and one on the ground managing the "sausage," charged entirely and only with the safety of the man or men aloft. For the observer in the air is wholly at the mercy of circumstance and the enemy. He has no means of defense against any attack, and can neither rise nor come down save at the will of those who manage his winch. The officer in charge on the ground, therefore, must have a capacity for continuous observation which will not fail at critical moments, and must also have a nice discriminatory power as to the relation between danger, wind velocity and strength of outfit. For these three factors are very delicately interwoven in any emergency that may arise.

It requires a certain time interval to get a captive balloon down. Its rate of ascent is usually controlled only by the capacity of the bag to rise—that is, its margin of lift over its weight and what wind pressure there may be. Its rate of descent is regulated by the speed at which the gasoline power-winch hauls in the slender steel cable. But the choice of that rate is where the necessity for keen judgment comes in.

In a high wind, for instance, the rate of hauling in must be much slower than in a calm, otherwise a strain may be put upon the cable or the fabric of the balloon which is beyond the limit of safety. On the other hand, a German plane coming up (coming down!) to attack a "kahko" has never been known to wait on the safe speed of hauling down. And if an unexpected and unseen attack develops, the balloon may have to come down at a speed beyond its factor of safety. It is the officer in charge below who must judge whether or not the chances of the balloon bursting or breaking away, due to too great a haul-in speed, are greater than the chances of the oncoming plane "getting" the captive sausage.



French Sausage Balloon Dogging U-Boats

They were frequently used for coast patrol work.

It has been said the balloonist aloft has no way to get down except at the will of the officer below. This is not strictly so, since every occupant (there are usually two together) is strapped to a parachute. This parachute is

A French Captive Balloon

A type employed in the early days of the war on the west front. Spherical balloons were used at first, but these proved unsatisfactory. The Germans soon introduced their "sausage" balloon, which rode steadily in almost any wind. The Allies in time improved on the German design, by introducing their Cacquot balloons.

folded into a canvas bag, attached to the outside of the basket. It is so folded that it must unfold as it is pulled out of the bag. The bag is closed with cotton cord ties, and the head of the parachute is tied into the bottom of the bag with more of the same flimsy material. The observer being strapped to the parachute has only to fall overboard; the weak cord ties break and down he goes, parachute trailing behind him. He has nothing to remember, nothing to do, but to get out when the danger is such as to make his hurried departure necessary. Unfortunately, our sporting enemies have been known, time and again, after having set fire to a balloon, to follow the parachuted observer down to earth, firing at him as they go; and more than one who landed safely, as far as the drop was concerned, reached the ground only with a Hun bullet in his anatomy.

Courtesy of Scientific American.

Reeling in the Kite Balloon

The cable which holds a kite balloon winds around a huge motor-driven reel or windlass. The tension on the cable is always a matter of anxiety for the balloon crew, who measure the tension from time to time with a special instrument, shown in this photograph.

PARACHUTE JUMPING AS A LIFE SAVER

As might be expected, these parachutes are most carefully inspected and most thoroughly tested. It is said that in no tests which we have been able to devise for them have they ever failed, except when frozen. They have been folded up wrong, the ropes tangled, folded up wet, and yet, when tested with sandbags of a weight equal to that of a man, they have invariably opened and brought the bags uninjured to earth. A frozen parachute, however, will not always open; and in such tests, the bags, falling a thousand feet or more, have entered the earth and then burst like an explosive shell.

Parachutes open at from four to five hundred feet from the point of departure. During that first plunge downwards the speed is practically that of an unimpeded falling body. After the parachute opens and the fall is checked the speed will be at about ten to fifteen miles an hour, depending on the weight of the man and the size of the parachute.

It is taught all officers from the very beginning that the only way to use a parachute when the necessity occurs is to use it quickly. A delay of a few seconds may be fatal. When a Boche aviator sets a "kahko" on fire, the moment the fabric burns through, the inclosed hydrogen ascends in one puff of flame. There remain the fabric and the valves, the ropes and the cordage, the basket and its ballast. All this, usually burning, drops as fast as a man. If the man doesn't get out of the basket fast, when he sees his balloon is fired, it is probable that he and the wreckage will go down together. Then when his parachute opens, he slows up, but the burning débris does not, and, striking his parachute, will set it afire in turn and one more balloonist will have "gone west" by going down.

When two men are in the balloon, and both jump, they must not jump together or they may foul. A young officer on the front lost his life by sending his companion ahead of him and waiting, watching, a fraction of a second too long before following—the burning fragments of the balloon caught him and ignited his parachute but a hundred or so feet from a safe landing.

Balloon officers are forbidden to practice parachute jumps. There is nothing in the

jump which can be learned, nothing to know that will help next time. And there is no use risking a valuable life if there is nothing to be gained. But you will search far and wide for the balloon officer who doesn't want to have the experience—which says much for the very evident safety of the modern military parachute and its certainty of opening and functioning.

The "kahkos" are filled, of course, with hydrogen. But in place of the former chemical generator which was for long an integral part of a balloon outfit, cylinders of compressed hydrogen are used, filled at a central station under high compression and shipped to the point of inflation. They are attached to a manifold, into which the released gas rushes by expansion, and from this manifold the gas is led through a fabric tube to the balloon. When filling balloons with gas, men are seen straddling the fabric tube with sand bags and cords—their duty is to choke the pipe on any alarm of fire.

GAS WHICH SUPPLIES LIFTING POWER

The gas is originally obtained by any one of half a dozen processes—sulphuric acid and iron, electrolysis, caustic soda, or the commercial process known as Messerschmidt, which uses superheated steam. Of these, electrolysis of course gives the purest hydrogen, and has the added advantage of yielding a by-product of oxygen which is useful in another department of aeronautics, the oxygen outfits for high altitude work in airplanes.

The purity of the hydrogen has much to do with the available lifting power of the balloon. Air weighs about seventy-five pounds per thousand feet and hydrogen about five pounds for the same quantity. A balloon, then, with a capacity of 40,000 cubic feet will have a lifting power of 2,800 pounds, if the hydrogen is pure.

The "kahko" balloon is in all respects to be considered a free balloon if it breaks away. It is provided with a valve—in the nose of the balloon rather than its top—and the familiar rip panel as well. It has also a ballonet inside for air inflation to accommodate expansion and contraction and the familiar neck of the spherical free balloon is absent. It is rare indeed that a "kahko" breaks away, for the cable which anchors it is constantly subject to the most searching inspection. Not a foot of it is paid out or hauled in that is not narrowly watched—indeed, the maintenance of the cable in perfect

© *French Official Pictorial Press, N. Y.*

A French Parachute

This illustrates how the apparatus is fastened to a man before his leap to the ground.

condition is one of the most important duties of the officer supervising the flight from the ground. If, however, a "kahko" does break away, the officers aloft are in as much control of the bag as they would be in a regular free balloon flight, having both ballast and valve, and in spite of the bound with which a sud-

denly freed sausage takes to the upper air, ordinarily there is small difficulty in making a safe and speedy landing. And there are always the parachutes.

The training of a "sausage" balloon observer is a combination of balloon, artillery control, map making and observation course. The observation training is intensive and growing in accuracy and magnitude all the time. Things look very different from one altitude than from another, and it requires considerable practice to distinguish accurately. Among other things, the judgment of distance of smoke puffs from a given object is taught, and in the ground training, this is accomplished by a unique little apparatus in which a landscape in miniature is provided, at different points of which small smoke puffs are observed from different distances and altitudes, the students learning in this fashion the rudiments of distance judgment and angle observation.

The balloon companies must know not only how to handle the balloon aloft but must be expert in taking care of it on the ground. In this we have learned much from both French and English. Conditions at the front change too rapidly to permit the erection of balloon sheds except at certain military bases, so the sausage is bedded behind huge wind breaks in the woods, if possible, and most scientifically secured to wire rope anchors. These most unmanageable objects have been so tamed that flights can be made even in high winds, and the sausage so anchored and protected from the weather, even in the open, that no wind storm short of a hurricane could make deflation necessary.

THE SUBMARINE PROBLEM

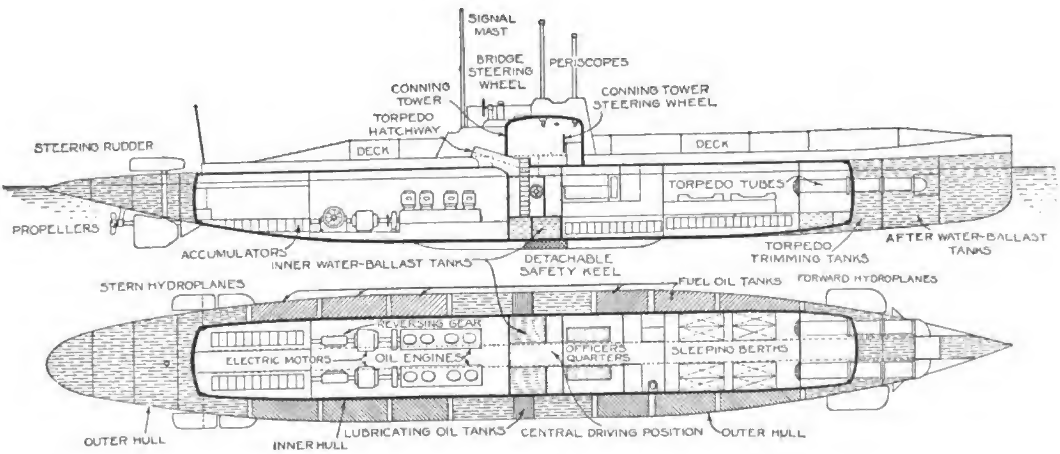
A Brief Account of the Battle of Wits between the German Naval Constructors and the Allied Inventors

SPACE is lacking to give any historical account of the development of the submarine, or to attempt any description in detail of the various types used during the war. In general the U-boat consists of an inner hull, circular in cross-section, and built to resist heavy water pressures, and an outer hull of conventional boat-shape surrounding this. The outer hull is open to the sea through valves, and hence has to support no pressure from without; it serves only to carry ballast, either of water or of fuel oil, and to make the craft subject to the ordinary principles of navigation when on the surface.

The submarine, in addition to the outer hull which must always be full of water or oil or both, carries in its inner hull a number of ballast tanks and trimming tanks, into or out of which water can be pumped to increase or decrease the buoyancy or to change or restore the balance of the ship. Submersion, it must be understood, is not effected by taking aboard enough water to make the ship actually sink. The tanks are merely filled to a point where the vessel runs almost entirely submerged, but still with a buoyancy of a couple of hundred pounds or so. The horizontal rudders or hydroplanes at bow and stern are then depressed, and the boat is forced downward by her engines. After this she is kept down by so disposing her four planes that the pressure of the water against them keeps her at the desired depth. In other words, the submarine is sent down and kept down in precisely the same way that the airplane is sent up and kept up—by pressure of the medium on her planes, due to the forward velocity. The submarine is far less flexible and less easily managed than the airplane, simply because her forward velocity cannot be got up high enough to create any extreme pressure. But there is the same fundamental distinction between a sub and a sinking stone that there is between the airplane and the balloon; submergence is a dynamic operation. Of course, after the vessel has submerged, if it becomes necessary to remain at rest, this can be done by pumping in enough additional water to

overcome the buoyancy; but owing to the incompressibility of water, this will make the ship seek the bottom, and is therefore feasible only when the bottom is near enough to the surface so that the pressure of the superincumbent water comes within the resistant powers of the inner hull. Further, if the submarine submerged too deep, her engines would not be able to pump water out of her tanks against the increased pressure, and she would therefore refuse to rise. Lying on the bottom, practiced extensively in the shallow waters of the English Channel, is possible only in such shallow waters.

The submarine has two power plants. She runs on the surface by means of oil engines. These generate more power than the propellers and lighting system consume; the excess goes into the charging of storage batteries. The instant the vessel submerges, so that the burning of fuel with the accompanying consumption of oxygen is out of the question, the engines are thrown out of gear and the propellers are driven by motors operated from the batteries.



Details of a German Submarine

There is a general impression that the submarine is a very delicate shell, requiring only the slightest blow to ruin it. This is hardly the case; for the outer false hull can be badly shot up or rammed without affecting the stability or the flotation of the inner hull. Before the submarine can be crippled, this inner hull must be reached by shell-fire, explosive force or the prow of a ramming vessel with sufficient force to open it or to start leakage along the seams.

The smaller U-boats which the Germans had in 1914 were capable of 14 knots on the surface and 7 knots submerged. The latest boats, of 800 to 2000 tons or even more, have a surface speed of 16 knots and can travel submerged at 9 or 10 knots. Cruising radius depends upon whether the most economical speed is constantly employed; under favorable circumstances it is as high as 5000 miles, and when there is access to hidden stores of fuel it may of course be practically unlimited. It must not be forgotten that, in spite of its name and its ability to travel submerged, the submarine is handled on the surface just like any other ship; that it travels best on the surface; and that it stays on the surface except when forced, for offensive or defensive reasons, to dive.

THE TORPEDO

Indeed, although the original intent was to make the submarine strictly an under-water boat and a torpedo boat, both these features were modified as submarine tactics developed. When it was realized how much of her time the submarine would spend at the surface, and how much more manageable she was going to be on the surface, it became clear that she ought to be equipped with a gun, which is more accurate than a torpedo anyhow; so the Germans got busy trying to make up a gun-metal which would not be attacked by sea-

water. In this they were successful; and hence we had the spectacle, so startling while it was still novel, of a submarine with a good-sized gun permanently mounted on her decks, with no protection in submerging beyond a plug to keep the water out of the barrel.

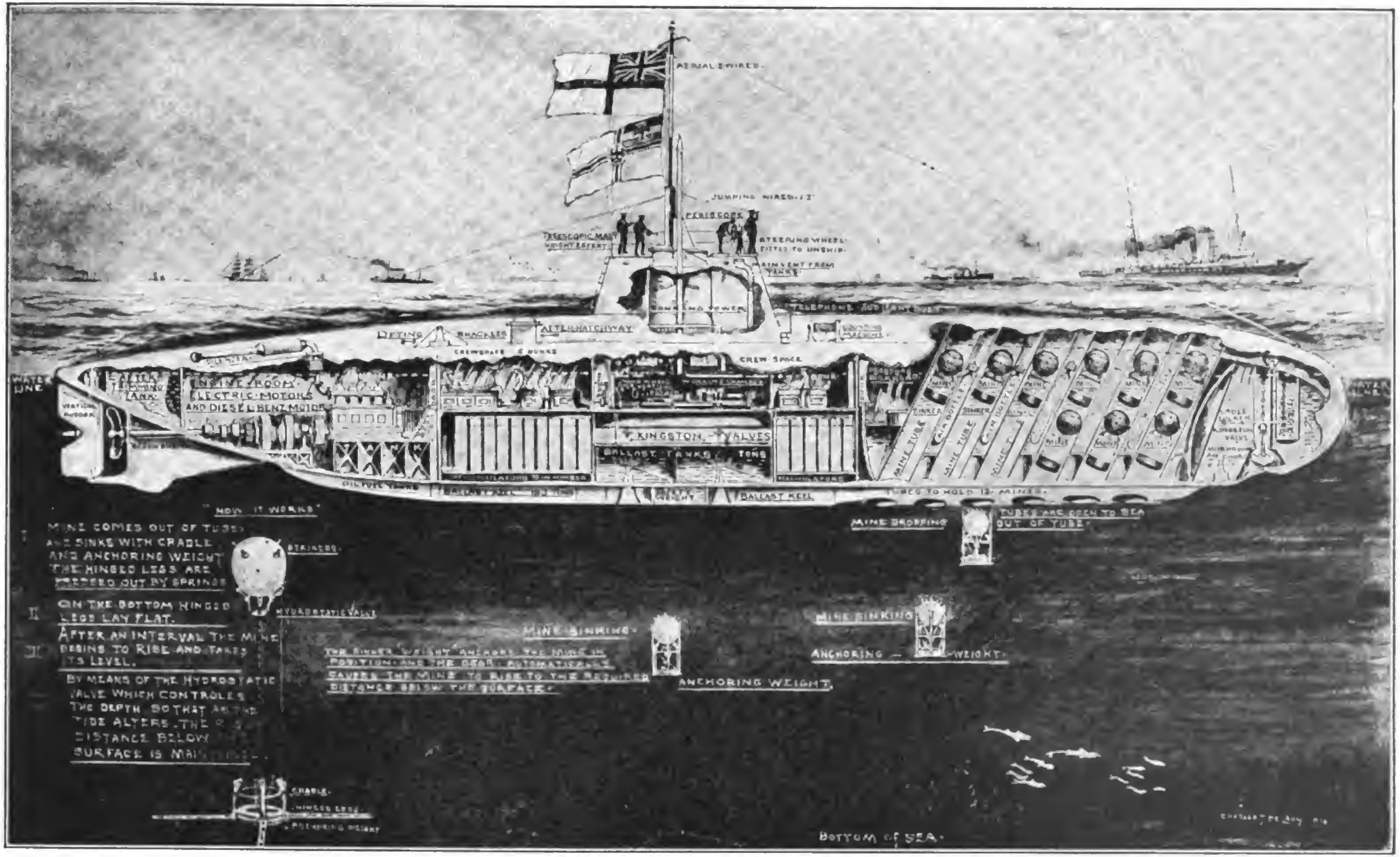
A word about the torpedo is also in order. This is really a little ship, carrying its own motive power and automatic steering apparatus. Of course compressed air is the motive power; it is stored at a pressure of about one ton per square inch, and released to the motor by a reducing valve that delivers it at a uniform working pressure of 200 pounds. The effective range is around 5000 yards. The horizontal rudders, which keep the torpedo from diving or leaping away from the depth at which it is set to run, are operated by a "hydrostatic diaphragm," which is rigid at the desired depth but is forced inward or outward at the greater or less pressures of greater or less depths. The vertical rudders which keep the torpedo on its course are controlled by a gyroscope rotating in a plane perpendicular to the line of flight. Whenever the nose of the torpedo tries to turn up, down, or to one side, the hydrostatic diaphragm or the gyroscope kicks it back into the proper line.

While the outstanding problem created by the submarine was the protection of merchant ships from its attacks, we must not lose sight of the fact that it had a very definite place in legitimate naval warfare. The British at the beginning undertook a tight blockade of the German coast; but a single attack by a single submarine cost them three first-class ships—and the submarine got away! It was this incident which forced a rapid change to the loose blockade, in which the Grand Fleet constituted merely the backbone of the blockading forces, and kept well out of the way of the submarines, behind a protecting screen of mosquito craft which did a goodly part of the work, and of mines, nets, etc.

It was easy enough to protect the Grand Fleet from submarines in the North Sea. But when the Allies were called upon to protect their merchant ships from submarine attack on the open ocean, they were confronted with an absolutely fresh problem. It was necessary to begin at the very beginning, to consider every idea of which human ingenuity was capable, to throw out those which were obviously impracticable or which after trial were found not to work, and gradually to develop the technique of anti-submarine warfare. This necessity was very often overlooked, and it was demanded that a completely effective remedy be hatched out overnight. The novelty and importance of the problem, moreover, attracted everybody's attention, and everybody had a suggestion to make for strafing the U-boats. An account of this public reaction to the submarine warfare is of interest on its own grounds, and is further of value as showing why certain things were not practicable and why the anti-submarine campaign finally took just the direction which it did take.

FISHING FOR SUBMARINES WITH MAGNETS

Of course all sorts of half-baked schemes were advanced by people who did not possess the knowledge, or even in some cases the good sense, necessary for rational attack upon the problem, and who did not seem to realize that a course of action which was perfectly obvious to John Jones of Mudville must be equally obvious to all the other John Jones's —and, if it were valid, to the Edisons and the Steinmetz's and the Spragues. For instance, there were thousands—yes, literally thousands—of letters received by the various branches of the government and by the technical societies and magazines, begging and imploring and commanding that the navy go fishing for submarines with magnets. The scheme was to lower electro-magnets into the water and trail them along, with the object of having them attracted to the sides of any submarines in the vicinity. Then the procedure varied; some advocated sliding a contact bomb down the wire, while others wanted to lift the U-boat clear out of the water by means of the magnets! Such propositions, of course, can be advanced only by those who are utterly ignorant of the nature of magnetism, and the fact that it acts, not along straight lines like practically all other forces, but along curved lines running from one pole of the instrument to the other. Accordingly while a magnet may act with tremendous



Courtesy of Scientific American.

Details of a German Mine-Laying Submarine

force over a very short distance, it can never have any range to speak of; the construction of a magnet that would fly to the side of a submarine from a distance of more than a foot or two would be wholly out of the question.

A little more promising would seem the suggestion that the compass be employed to reveal the presence of the submarine—until we stop to ask what are the probabilities that the compass thus employed would be free from the attraction of considerable masses of iron aboard the ship on which it was mounted.

PROTECTIVE NETS AND PLATES

So much for the proposals that were absurd. But aside from these, from men of technical ability and experience all over the country there emanated a vast number of suggestions which were sufficiently plausible to demand close consideration; and it is of these that we would speak at some length. It is almost inevitable that, in the search for some quickly improvised protection against the submarine, the mind should think of placing an obstruction of some sort in the path

© Scientific American.

A Device for Destroying Enemy U-Boats

Inventors in every country spent months thinking up schemes for attacking the U-boats. One of these schemes was a net, floating in a vertical position some distance below the surface. Provided with a suitable tell-tale, this net collapsed the moment a submarine struck it, and became wrapped about the submarine. The tell-tale then informed passing submarine chasers, whose crews passed a bomb down the trolley leading to the submarine ensnarled in the net.

Then we see that this, too, is visionary. The man who proposed the magnet merely demonstrated his ignorance; the fellow who suggested the compass exposed his lack of common sense. Another foolish notion was that of hanging nets of live wires in the submarine paths. The innocent sub was expected to poke her nose into one of these, and at once create a short-circuit, which would ring a bell or blow a whistle or shoot off a bomb. The man—and his name was legion—who proposed this did not even know that salt-water is such a good conductor that the net would be in a perpetual state of short-circuit. Yet he took his hand at solving the submarine problem!

of the torpedo that would arrest or explode it at some distance from the attacked ship. It is very easy to believe that detection of the presence of the concealed submarine is going to be a thankless task; that it were better to accept its presence, to let it shoot, and to prevent the blow from coming home. But actual trial of a very wide variety of protective nets and plates demonstrated that none of the plans proposed would work, and convinced the Navy that no workable plan of this sort would be possible.

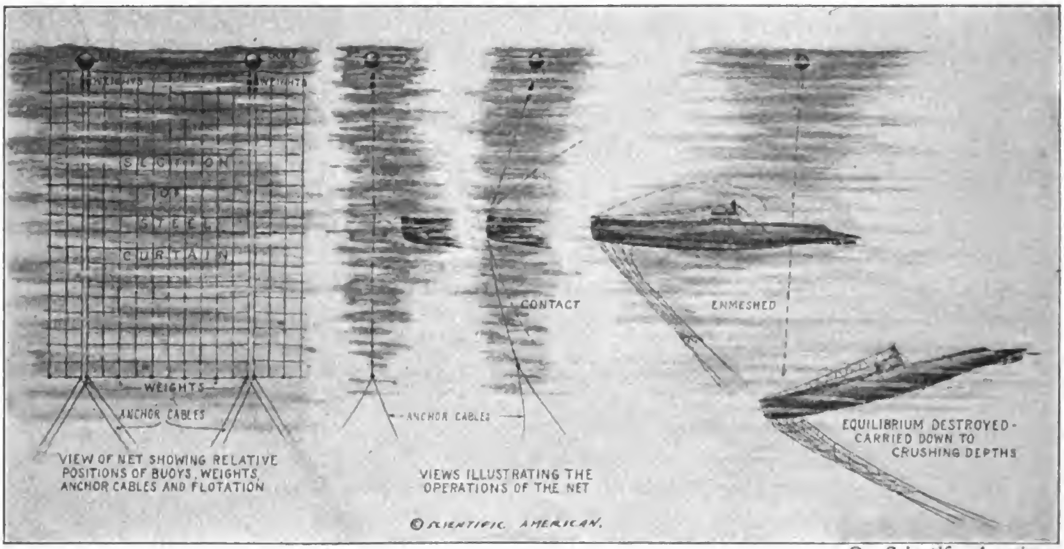
In the first place, it is not enough to check the torpedo before it can strike the ship's side. Torpedoes are made with contact firing-pins, to be sure; but they are also made with

Forming a Smoke Screen

Using smoke boxes to foil a German submarine. These smoke boxes are arranged to burn the moment they strike the water. The dense smoke serves to screen the merchantman from the U-boat.

inertia firing-pins. The fact that the torpedo is traveling at a speed not far from thirty miles an hour is what counts here. If you are going to check this speed, operating from the attacked ship, you must check it pretty suddenly or you will be too late; and when you check it suddenly you have the same phenomenon that throws people forward in a car on a sudden application of the brakes. The torpedo firing-pin is so arranged that such a stoppage throws the contact forward against the primer, and the torpedo goes off torpedo explosion, that explosion must take place no less than thirty feet from her side. This disposes at once of all close-rigged plates and nets; the ship has got to drag the protective devices through the water and hold them 30 feet off-board.

There is grave doubt whether any such outrigger could be devised that would not call for more motive power than the ship could spare. If you do not easily credit this statement, go out for a row and get somebody in the boat to drag a hand in the water. You



© *Scientific American.*

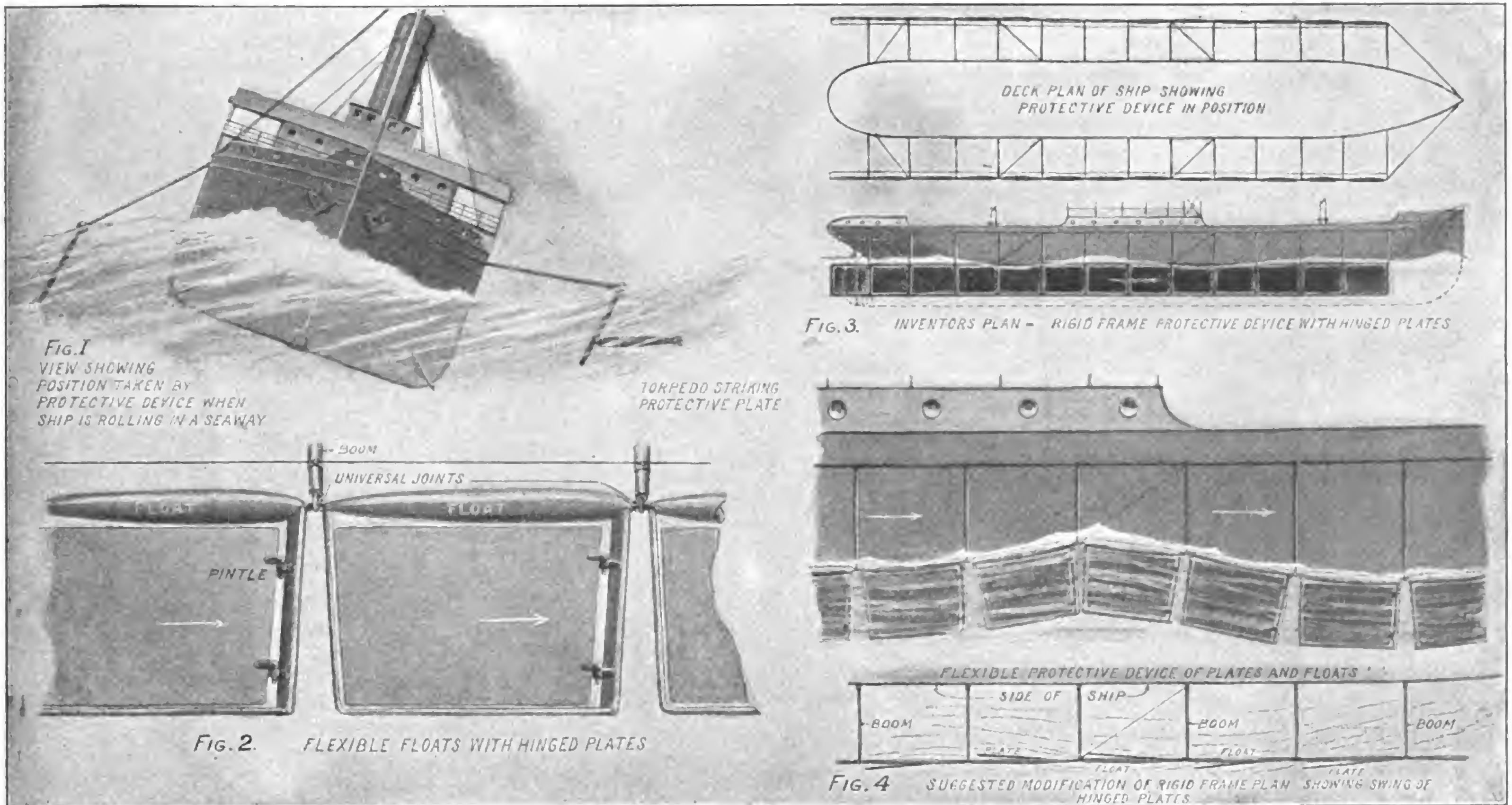
Trapping U-Boats

Of the various schemes for trapping U-boats, nets were widely used. Here, for example, is shown a typical submarine net. The U-boat running into such a net was enmeshed in the manner shown, and its equilibrium destroyed. The submarine was carried down to crushing depths, not by the weight of the net, which was insufficient, but simply by the loss of balance.

by virtue of having been merely arrested in its flight, regardless of whether any contact has been made. This disposes of a lot of suggestions that the sides of the ship be equipped with flanges or deflection plates which would stop the torpedo or turn it off without making contact with the firing-pin.

In the second place, water is almost wholly incompressible. An explosion in water is therefore transmitted for a long distance—just as a blow on the top of a rigid spar a hundred yards long would be transmitted to the base. Best estimates are to the effect that in order for a ship to be safe from a will be amazed at the amount of extra power which you have to put into the oars to drag that hand along. An equally serious difficulty comes up in the matter of steering. The experiment of the rowboat and the hand will again convince anyone that heavy metal plates dragging from the boat would make it utterly impossible for her to answer her helm. But even waiving both these points, there remains the fact that nobody has yet devised a protective plate that will stand the gaff.

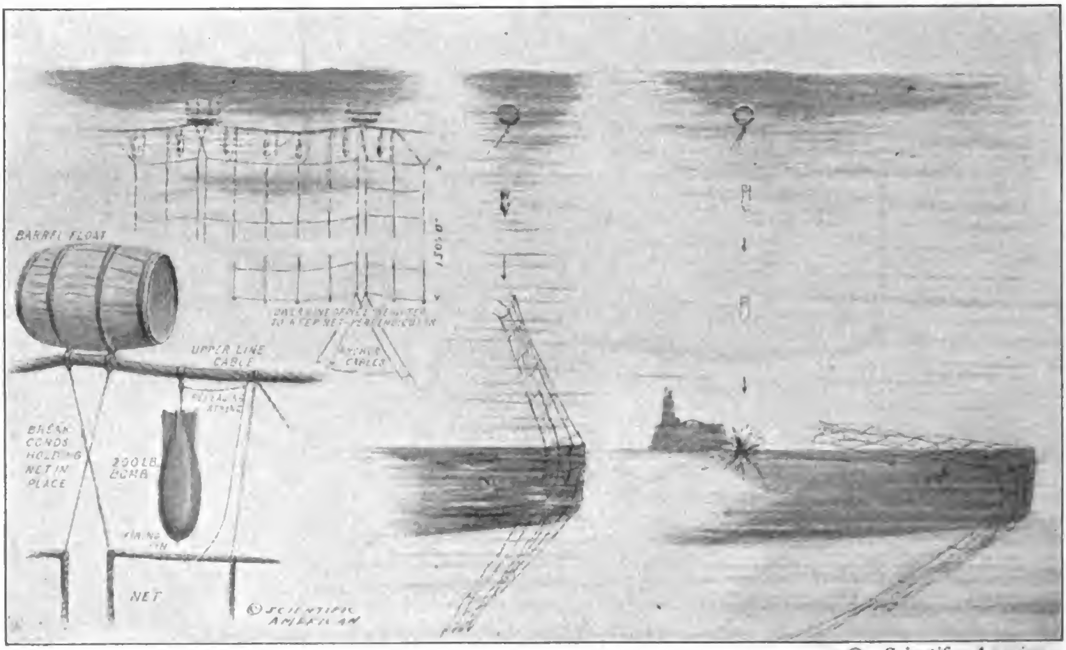
Is it to be fastened rigidly to the vessel, so that as the ship rolls sideways the plates



Inventions for Protecting Ships Against U-Boats

The anti-submarine campaign brought forth no end of ideas from inventors in America and abroad. Among the schemes suggested were ship protectors in the form of plates, carried by a ship as shown in this illustration. Such schemes, generally, were impracticable because of the great weight and head resistance of the outrigged apparatus, which cut down the speed of the ship greatly.

roll also? Immerse a shingle in the bath tub, and try to remove it by rotating it upward, about its upper edge as an axis. Then imagine a heavy metal plate, hundreds of feet long and thirty or forty feet deep, trying to roll against the pressure of the whole Atlantic Ocean. Of course it would be torn loose from its moorings the first time the ship gave a roll that amounted to anything.



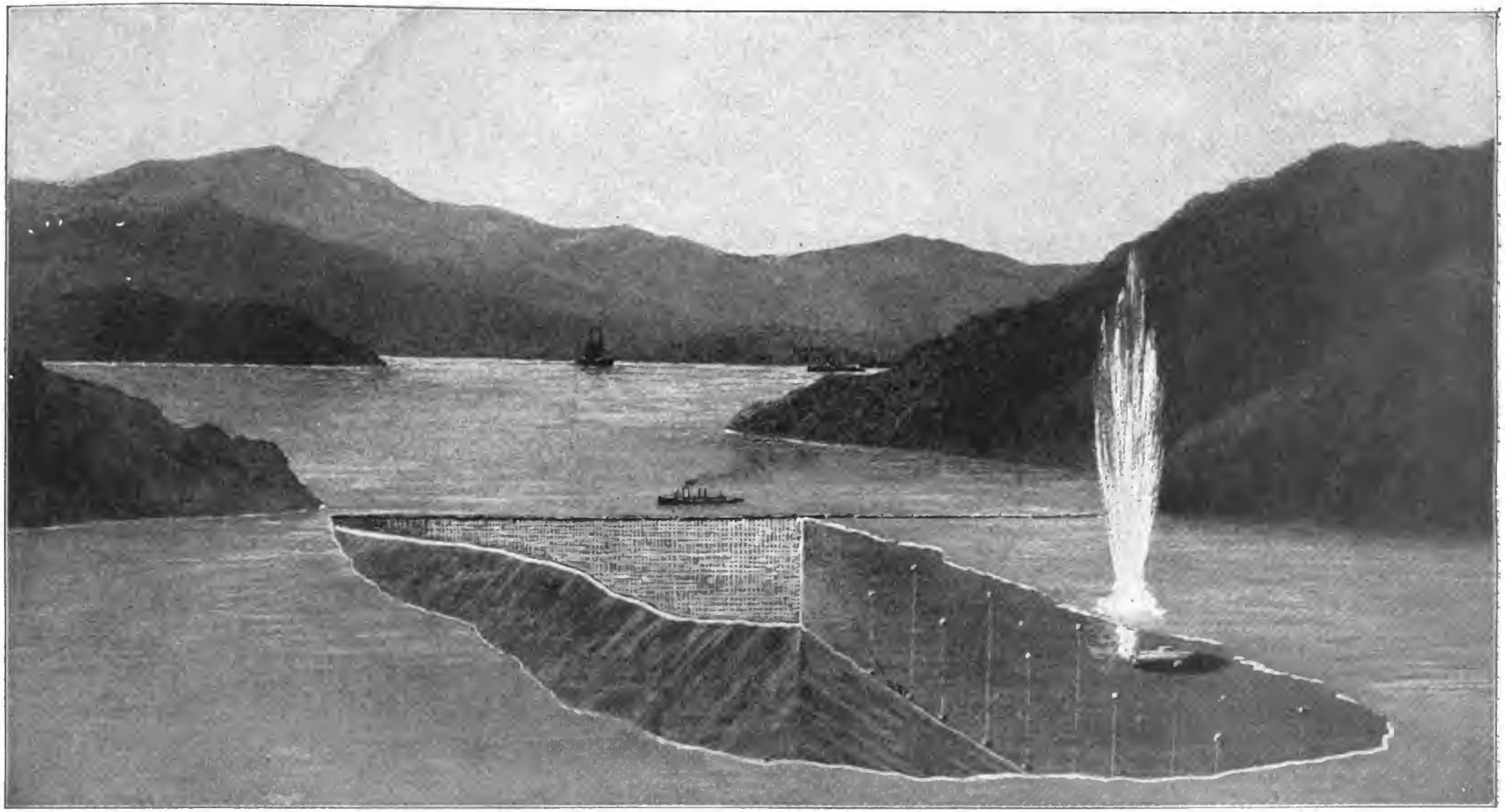
© *Scientific American.*

One Method for Trapping U-Boats

One of the schemes suggested for trapping U-boats is shown above. A submarine net, provided with barrel floats and pointed bombs, was to be floated in an upright position. When a submarine ran into this net and broke it away from the barrel floats, the net fell over the submarine and brought down a shower of pointed bombs, which exploded on contact.

WATER PRESSURE AND ITS RESULT

On the other hand, suppose that it be not rigidly attached. It is entirely clear that in this case, as soon as the ship gets up a decent speed, the plate will be swept up to the surface. A fisherman will tell you how much weighting it takes to keep a single line submerged, in the wake of a slowly-moving skiff. How much more would it take to keep a huge steel plate submerged as it keeps pace with a fast steamer? The sweep of the water will carry it up, in spite of anything you can do—unless you put such weights on it that all the coal in the world will not move the ship faster than a crawl. A great many ingenious devices—pontoons, self-steering nets, etc.—were got up in the dark days of 1917-18 in the effort to get away from the buoyancy of the net or plate without creating too much resistance to the passage through the water; but all failed. One ingenious inventor, who failed to realize that there was anything to it outside the resistance of the water to the forward motion of the plates, came all the way from St. Paul to New York to get drawings made of an endless belt which should revolve at the ship's side. The lower lap of the belt would travel toward the stern at precisely the ship's speed; it would therefore be stationary with respect to the water. The upper lap would travel forward, but up clear of the water. The protective netting of chain-steel would be carried on the belt in such a way that it would hang down and screen the ship on the backward trip, but would not



© Scientific American.

An Anti-Submarine Mine Field

Submerged nets and mine fields were employed to a great extent during the war for hampering the operations of submarines. The Dardanelles, for instance, were blocked by nets and mines, but these did not prevent Allied submarines from penetrating to Constantinople.

clog the running gears on the forward trip. But of course, the whole thing would have been ripped bodily off the ship at the first touch of heavy weather.

Abandoning then the theory of nets or plates for protection of the attached ship, and clinging still to the idea that detection of the submarine's presence was not to be attempted, the logical step was to blockade the subs and thus keep them out of the ocean lanes. In other words, to use nets, but make them stationary, and locate them so as to protect, not a single ship, but the whole region in which ships were being operated.

A PRIVATE POND FOR THE U-BOATS TO PLAY IN

This, at first glance, appeared to be utterly out of the question. We could not get into the shallow waters off the German coast to set up an actual blockade of the U-boat bases. We had to block off large areas of inland waters on which those bases open. It would not even be enough to blockade the whole North Sea with a net from England across to Norway; we had at the same time to block off the English Channel outside of Zeebrugge!

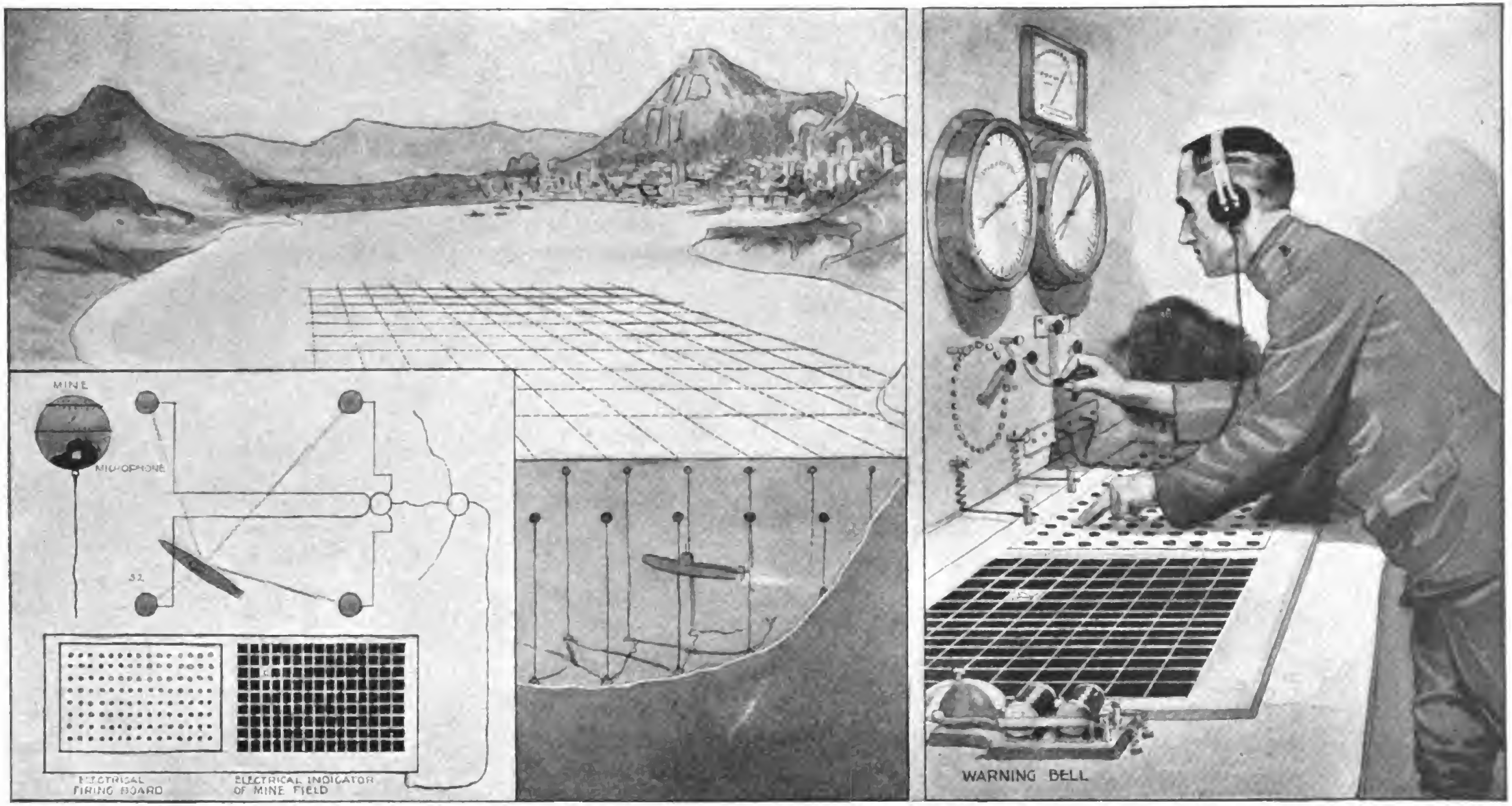
Gustav Lilienthal, the bridge engineer, once remarked that if he were given unlimited money and unlimited men he would undertake anything whatever. That he meant what he said is evidenced by the fact that this remark was made in connection with a discussion of the feasibility of bridging the Atlantic. In the late war the respective belligerents came closer to this ideal of unlimited men and unlimited resources than the human race ever before attained. We need not then be shocked to learn that the fencing off of the North Sea and the Channel into a private lake for the submarines to play in was actually attempted, and accomplished with a moderate degree of success.

It was not done with nets—at least, the 300-mile passage between Scotland and Norway was not netted. It was concluded that the maintenance and especially the defense of such a net would be too much of a problem—the construction was not balked at. What was done here was to plant a tremendous mine field—millions of mines, so scattered that it was hoped that few submarines would find their way out. As for the Channel, across which the huge artery extended connecting England with the fighting front, that was something else. It was only 25 or 30 miles, and it was of vastly greatly consequence to keep it free of submarines. Here the net was used, and with conspicuous success.

Much discussion was given as to the character of the net to be employed. Should it be merely an entanglement, or should it be a framework carrying bombs? Largely in view of the known fact that the German submarines were fitted with net-cutting devices, consensus of opinion inclined toward the latter and more immediately destructive measure. The bombs would have sufficient buoyancy to carry themselves and part of the net in addition, so that the size of the necessary flotation buoys would be materially reduced. Moreover, a net that would stop a 2,000-ton submarine would be a pretty husky affair, while it would be comparatively simple to manufacture enough mines to insure that any submarine hitting the bomb curtain would be in contact with one of them—if not directly, then by drawing the net in after it.

Of course this barrier required constant patrol and guarding, both for its protection and for its repair. This was given by the great numbers of small craft of various types at the control of the British Navy, and by airplanes and dirigibles. Perhaps the greatest difficulty was the designing of a firing-pin that would go off without fail on contact with a ship, but would be stiff enough *not* to go off from the shock of detonation of one of its neighbors, thus destroying the whole net the first time a U-boat was caught in it. An ingenious touch was the locking of the firing-pins in the safety position by means of a cement soluble in water, so that the bombs might be freely handled in the laying, becoming alive only after having been in the water for some time.

The interval between the first serious consideration of the mine barrage and the final step in its execution was necessarily a year or more, however; so the decision to adopt this measure, and the expectation that it would be successful by no means closed the matter out. It was not possible to give the submarine full sway for any such period, even



A Checker-Board Mine Field

Here is a scheme for a mine field laid out in checker-board arrangement. . Each mine is provided with microphones or electrical ears. As a hostile ship picks its way through this mine field, the noise is picked up by the microphones of the nearest mines, and sent to the switchboard at the firing station. Then the mine nearest the ship is exploded electrically, no contact being necessary.

in anticipation of a means of completely subduing it thereafter. Oddly enough, much of the attention which was given the problem just at this time was concentrated in another direction which was open to the identical objection of loss of time. It was seriously proposed on many sides to pass the buck right up to the ship-builder. This attack upon the problem took several forms.

© Scientific American.

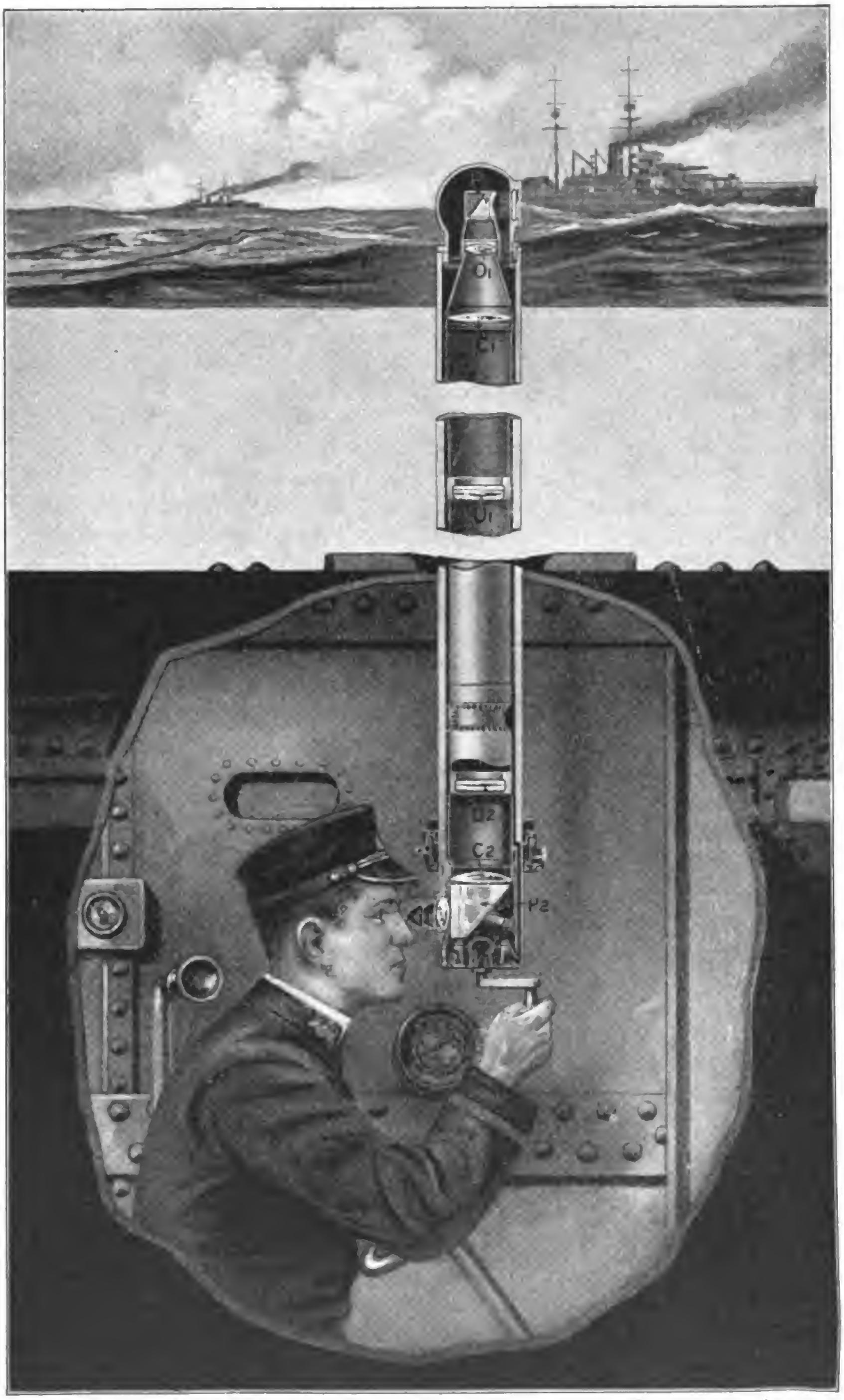
A Trick of the U-Boat

One of the artifices tried by the U-boat commanders was to place sails on the wireless masts of their craft, in this manner giving their boats the appearance of an innocent sailing vessel.

SWAMPING THE SUBMARINE WITH WORK

In the first place, there were those who resigned themselves to the submarine and said that there was obviously no cure for it. The only thing to do, according to these cheerful souls, was to build merchant ships in such vast numbers, and send them to Europe loaded with such vast quantities of supplies and munitions, that the best execution the submarines could effect would not be good enough—that the ships that escaped would be sufficient to win the war. This extraordinary point of view was seriously promulgated, without any apparent thought as to where the men to man these doomed and defenseless vessels were coming from, or how out of the question it would be to attempt sending the American Army over on such a basis, or how long the supply of wheat and steel and cotton would last under such wastage.

People who had better sense than to attempt thus to gorge the submarine beyond its capacity were inclined to look to a modification of ship design to afford the answer. Put in so many water-tight bulkheads that at the most a torpedo can only open two or three adjoining compartments, they said—overlooking that the ship thus crippled could only limp along until darkness made it safe for the U-boat to close in and finish her off with gunfire. Or others were for a modification



The Submarine Periscope and its Working Parts

It will be noted that the rays entering through the top lens or "eye" are reflected down the long tube and passed through the eyepiece in the operating quarters of the submarine. Provision is made for turning the top lens about, so as to aim the periscope in any direction.

of the protective net which should be an integral part of the ship—that is, they advocated a sort of protective blister thirty feet in depth running around the ship, so that neither torpedo nor shell could do more than pierce the outer hull. Of course a ship so designed could carry a cargo amounting to but a fraction of what she would have to carry to justify sending her across the ocean. Then there was the suggestion of shipping goods to Europe in huge barges, which when loaded would lie practically flush with the surface of the sea, and which were to be towed across the ocean by giant tugs. On the approach of a submarine the tug would abandon its tow, to come back for it later, picking it up by the aid of buoys. The submarine was not supposed to be able to do the same thing; or if the extreme optimism of this viewpoint were recognized, it was pointed out that the barges would lie so low that they could hardly be sunk by shells, and that only a dozen or so of them could be sunk by one submarine with torpedoes. The possibility of the U-boat lying in wait for the return of the tug, or of her crew boarding and broaching the barges; the extremely low speed which towing involves; the enormous risk of the towing lines breaking under the buffeting of heavy seas—these were all overlooked.

A QUESTION OF TACTICS

After a couple of months in which suggestions of this order predominated, it was at length realized that there was no time for anything of the sort—that the ship yards would do their best to turn out ships, but that the whole onus of meeting the situation could not be placed on them. In the meantime, the tactics of submarine attack and defense had been undergoing some modification. At the beginning of unrestricted submarine operations, the U-boats had come boldly to the surface in the vicinity of their prey, hailed the latter, and destroyed the luckless ship at leisure with gunfire. The surprise attack with torpedo was only experienced when there was good reason for keeping the presence of the submarine a secret. But this happy procedure was rudely interrupted when the merchant ships began to carry guns. It was even more roughly shaken up when, the extreme desirability of this protection having been realized, the merchant ships began to carry guns that actually outranged those of the submersibles. Under such circumstances the U-boat captain could only come to the surface for a look and a shot with his torpedoes, or pursue the armed merchantman until nightfall gave an opportunity to close in unobserved. It was utterly out of the question to come clean to the surface and engage in a gun duel with a fellow who outranged him and had heavier metal in the bargain.

Eventually, however, the submarines discovered that they had not such a bad bargain as it had for a while seemed. Gunfire is amazingly accurate; but you can't expect a gunner to hit a six-inch mark at a distance of a mile or two. When the submarine rides with her periscope out, that is all the mark she presents; for her hull is under water, and a shell that hits the surface of the water at a low angle will not penetrate at all, but will simply bound or ricochet, as the term goes. There was frantic search on the part of the Allies for a non-ricocheting shell, a shell that would strike the water at an angle of say five or ten degrees and go right on in its course, entering the water and striking its mark beneath the surface instead of bouncing off the surface into the air again; but in spite of rumors to the effect that such a shell had been developed, it remained impossible for gunfire to disable a partly submerged submarine in any other way than by a direct hit on the exposed, visible parts about the base of the periscope.

Baffled in so many directions, then, and with the conviction growing that the merchant ship could hardly expect to elude the submarine, those who were seeking to defeat this new instrument of war came reluctantly to the conclusion that, after all, they would have to seek some means of locating the submarine and carrying the fight to it. Defensive measures had not scored a success, and it was necessary to go to the offensive. But before all else this meant finding the submarine. If we can find it, we may hope to find a way to destroy it; but until we know that we can find it, it is idle to think of destroying it.

FINDING THE SUBMARINE

There are a number of principles which, after careful study, were held either to possess special promise or to be entirely misleading. Prominent among the suggestions offered by inventors was that of using some sort of optical instrument, such as an inverted periscope, for seeing under water. The fact is, however, that such instruments are useless at distances that amount to anything. Under the best of conditions one cannot see through more than a hundred feet of sea water, and even then objects are hazy and devoid of detail. Beyond that distance, at depths of thirty feet or more everything blends into a dark green background. This statement applies to direct vision through a two-inch thickness of optical glass, and is based on experience in submarine motion-picture photography. Even with the aid of powerful illumination no improvement is possible; and this brings us to the second point.

The use of submarine searchlights was suggested; a typical plan was to employ a beam of red light, which according to the inventor could be seen by an observer in the crow's nest stretching out from the hull of the ship to a distance of several miles. The idea here would not be actually to see the submarine by light reflected out of the water from its sides; but the submerged pencil of light, it was claimed, would be plainly visible and if at any point it impinged on a submarine it would be there broken, and this would be clear to the observer. But the facts are that it is quite impossible to penetrate water for any distance with any kind of light whatever, daylight included. It may be true that red light would serve this attempt better than white, because of the contrast with the green water mass; yet the fact remains that its penetrative power would be less than that of daylight. Two hundred feet is the maximum penetration of any sort of light in water, and this of course is totally inadequate.

Salt water is a pretty good conductor of electricity. So a good many inventors suggested making use of electrodes arranged in the form of buoys, and measuring the resistance of the water between pairs of these. Under normal circumstances this resistance would not vary appreciably; but on a submarine's passing through the space between the electrodes, its huge bulk, several times that of the electrodes, would materially affect the resistance of the circuit, allowing more current to flow.

All this sounds very promising; but on final analysis it falls in the realm of ideas that will not work. The salt water is such an excellent conductor, it is found, that substitution for it of the metallic body of the submarine would not cause very material drop in resistance, unless the electrodes were so close together as to imply that we knew where the submersible was, all the time. True enough, if there is to be any drop in resistance at all (and obviously there will be), we can make instruments that will record it; but such an instrument would also record the far greater drop in resistance due to some infinitesimal speck of foreign matter on the surface of one of the electrodes or in the sea, and would hence be perpetually registering submarines where there were none.

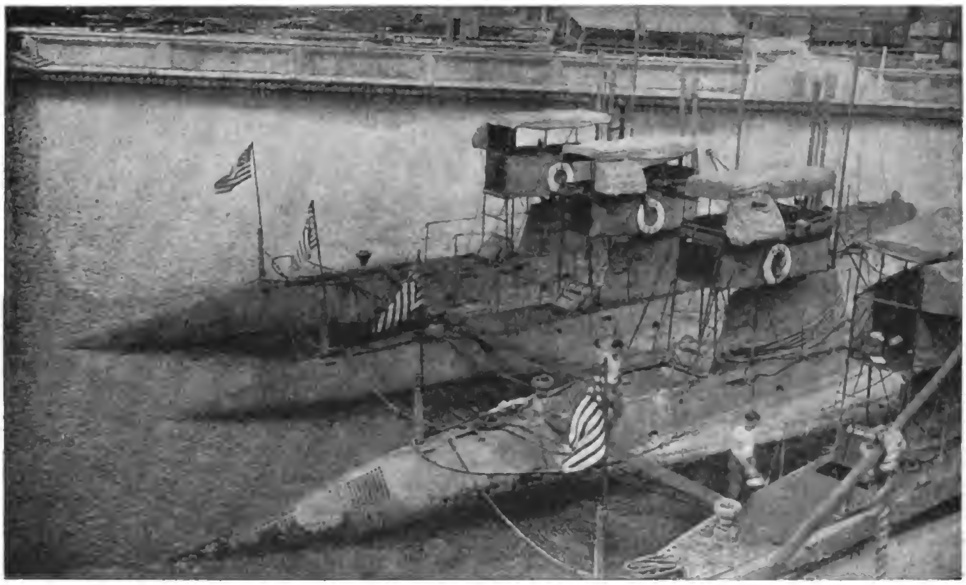
Very interesting are the tell-tale tags which were proposed from various quarters. The idea here is to strew the ocean with nets, suspended vertically, and attached to a surface buoy of prominent design. As long as the net rides at rest nothing happens; but the minute a submarine pokes its nose into the net and takes the latter away with it, the surface buoy gets a ride, too; and the alert watchers thereby trail the submarine and blow it out of the water. We recall a bit of fiction in which a submarine is thus accidentally tagged by means of a hatch cover from a sunken chaser; and the whole idea is eminently practicable, except for the tacit assumption that wherever the sub goes, there is some hostile chaser ready to jump on it. Doubtless the German crews got to feel this way about it, but the facts were not quite so favorable for the Allied cause.

THE HYDROPHONE

After all, when everything is said and all the returns are in, the means of spotting the submarine which shows most promise *a priori*, as well as the one which scored most heavily in actual use, is the one that comes from de-

liberately putting away the natural feeling that to find means to see. We eye-minded folk are far too apt to fall slaves to our eyes, when in many things we would do better trusting to other senses. A normally hearing person will not believe, until he tries it—perhaps with a bit of practice—how closely he can draw the line between different sources of sound, and sounds that come to him from different distances. And so in the campaign against the submarine, final success and comparative infallibility in knowing when a sub was about and in spotting its precise location came only when we learned to let the ears do the work which seems to belong to the eyes. The hydrophone has been described in an earlier chapter, and we need say nothing further about it here save that it was the last word in submarine detection. It put other methods out of commission, no matter how promising they might have seemed, simply because with it no other method was needed.

It is of interest to note that the inventors who got this far on the right track were not at first sure that the submarine would give out sufficient noise to serve as a means of location. Accordingly there were a good many devices which aimed at the radiation of sound waves into the water by the searchers—sound waves which would never be heard from again under ordinary circumstances but which would be reflected back to their source when there was a submarine in their path. But this refinement, although perhaps available in peace for detecting the presence of icebergs, in war was not found necessary; under all circumstances the moving submarine gives forth sounds which can be picked up by microphone at amazing distances. The Germans tried mounting the machinery on special bases which it was hoped would be completely vibration-proof; but they found that the only way in which they could defeat the exaggerated sound-carrying powers of water and the extreme delicacy of the microphone was to sit quietly on the bottom. And of course this could be done only temporarily; the minute the sub started away, any chaser in the neighborhood would get her trail of sound waves.



© *Underwood and Underwood.*

American Submarines

These under-sea craft were utilized to fight their own kind—the German U-boats.

When work began on listening devices for use against the submarine, it was only hoped to make these a means of escape for the threatened merchant ship, which, with accurate information of the U-boat's whereabouts, would usually be able to avoid the

latter. The periscope does not extend far enough out of the water to give the submarine a wide horizon; the clatter of her own machinery makes it out of the question for her to use the hydrophone in locating her prey; and when in actual pursuit she must remain submerged with consequent reduction in speed. On every ground, if the merchantman locates the submarine first it should get away.

When the hydrophone was finally ready for use, however, there was more to the matter than this. From the original supposition that no effective attack could be made on the U-boat, knowledge of the possibilities had broadened until naval men boldly challenged the inventors with the statement that if they could be given a sure means of finding the submarine, they would destroy it with reasonable certainty. The hydrophone gave them the necessary means of location, and they at once proceeded to make good their boast. Their instrument was the depth-bomb.

DESTROYING THE SUBMARINE

We have already indicated that a torpedo exploding within thirty feet of a hull will damage that hull. An explosion is, first and last, a mass of expanding gas. If it has no immediate place into which it may expand, it will seek such a place. When confined by a thin, rigid wall, that search takes the direction of blowing out a section of the wall. When confined by a heavier wall, of which a section can be moved away bodily (this is the situation in a gun-chamber, the projectile representing the removable section), the expanding gas moves away that section and finds a vent. Under all circumstances, unless confined from every side by something capable of withstanding the pressure developed, the gas will find its vent.

When explosion takes place in water, we have a peculiar state of affairs. Water is to all intents and purposes incompressible. The only way, then, in which the gas of a subaqueous explosion can find vent is by ripping a path through the water to the air, or by driving the water before it and thus creating room in which it may expand. If it follows the former alternative, there is a violent surface upheaval of the water. It is when it follows the second course that the side of a nearby vessel is stove in. The explosion, whatever its distance from the side of the vessel may be, simply acts through the rigid mass of intervening water to deliver a blow against the ship, just as a blow delivered at one end of a rigid pole would be transmitted to the other. The water acts like a huge sledge-hammer and tears a hole in the side of the vessel. And it is able to do this because, on the inside, the necessary support is lacking. There is, inside the ship, the space of free air into which the water can be driven, thus giving vent to the explosion.

The emphasis which discussion of the submarine problem had placed upon the ability of a torpedo to damage a merchant ship from a considerable distance led inventors to realize that a mine or bomb would similarly damage a submarine if it exploded anywhere in the immediate vicinity—that there was no necessity for contact. This is the first idea behind the depth bomb. We have simply a big can of explosives which is heaved overboard near the spot where a submarine is known to be hidden. After it gets in the water, it explodes; the result is fatal to the submarine if she is within the underwater range of the explosion. The only thing left to discuss is the means of bringing about the explosion. This means was again borrowed from the torpedo, with its hydrostatic diaphragm.

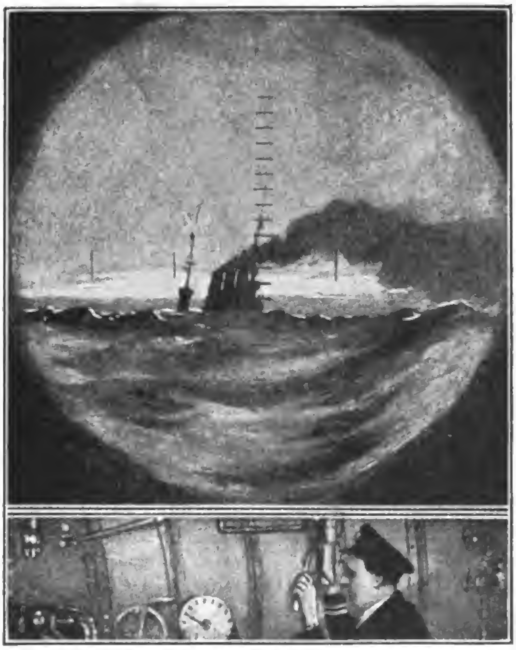
It is obvious that a diaphragm can be constructed that will resist without deformation any given pressure, but will be deformed and depressed by a pressure greater than the given one. It is equally obvious that as we go deeper and deeper in the water we get a greater and greater pressure. This is not due, in any measure, to compression of the water by the weight above it; its cause is simply and solely the increased weight itself. At a depth of a hundred feet there is ten times as much water as at a depth of ten feet; therefore there is just ten times as high a pressure.

Very well; that is how the depth bomb works. Its firing mechanism comprises a diaphragm which can be set for any depth desired —which means for any pressure desired. Then when it is thrown into the water, and when it sinks down through the water, the diaphragm will act as soon as the given depth

is exceeded; and with the movement of the diaphragm we have the impulse necessary to bring about detonation.

THE COMPLETE ANSWER—HYDROPHONE PLUS DEPTH BOMBS

There, then, is the final word in the campaign against the submarine. First hang a curtain of mines across the North Sea and the Channel, not with the idea of keeping all the submarines bottled up, but simply to reduce to a minimum the ones that have to be chased about the open coasts and the deep waters and caught. Have a huge fleet of small, fast vessels, equipped with hydrophones and a plentiful supply of depth bombs. When a submarine is detected, follow it up and sail above it; drop off two or three depth bombs and get away in a hurry—because the explosion can develop enough power, even at depths of thirty and forty feet, to blow the stern half off a destroyer. Have all merchant ships and all transports sail in groups, under heavy convoy. And the trick is done.



British Submarine's View of a Doomed German Warship

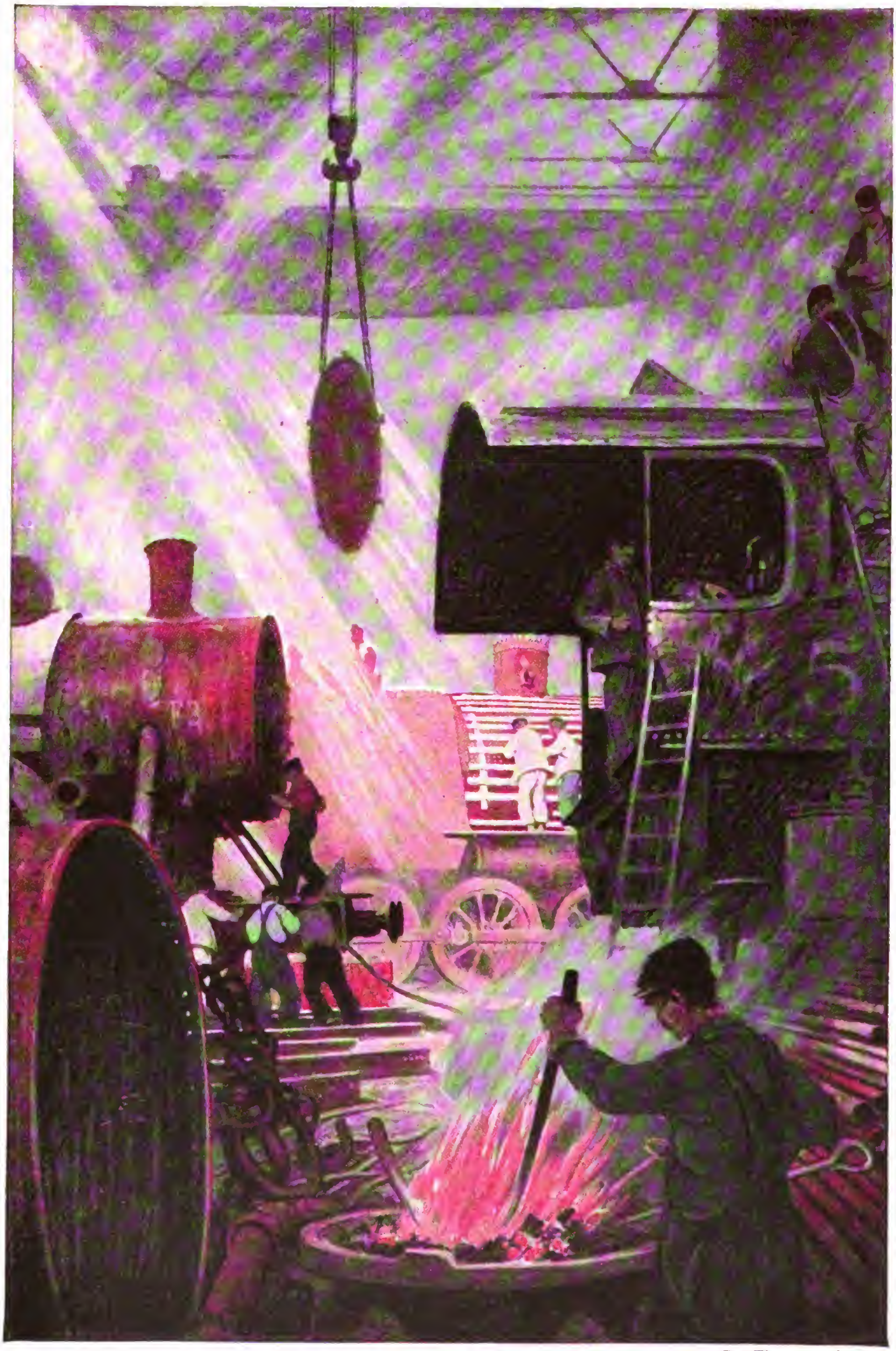
The "field" of a periscope—the marks denote measurements by which the distance of the ship can be gauged.

A word about the convoy idea. One might be pardoned for supposing that the reason for the convoy was simply to have help at hand against an attack. Well, in a way that is right; but tactically the matter goes a little deeper than that. If ships never sail alone, if they are only to be found in groups and accompanied by destroyers, obviously the submarine can operate against ships only in the presence of destroyers. It can operate only in the neighborhood where the efficiency of the hydrophone is multiplied by numbers, and where the certainty of destroying a U-boat once she has been discovered is similarly high. There can be no more sneaking around the shipping routes and picking off single vessels in secrecy and security. The submarine must work under conditions of the greatest risk, and hence with maximum losses. We not only protect the ships, but we actually destroy the U-boats in the bargain!

As to the magnitude of the maximum risk under which the submarines had to operate after the hydrophone and depth bomb were brought into effective partnership in the work of finding and destroying them, we can accept the testimony of the U-boat crews. Double, triple, quadruple pay was not sufficient to induce volunteers for these hopeless enterprises, once the men realized how many submersibles were sailing out of the German harbors and how few were ever coming back. In the space of a few months crews could not be got on any terms, and the effort to recruit them by force was the main factor in precipitating the naval mutiny which spelled the beginning of the end for the German war lords.

THE SMOKE TELEGRAPH

The smoke screen as camouflage or as a means of seeking invisibility is familiar enough. It was also used as a signaling device. Puffs of smoke can be given forth, from a properly regulated device, of sufficiently different lengths to pass for the dots and dashes of the Morse alphabet, and to be clearly distinguishable from one another. This curious mode of telegraphy was used more by airplanes than by any other branch of the service.



By Thornton Oakley

Building a Locomotive

PART IV. THE ENGINEER AT THE FRONT

THE RAILROAD IN THE WAR

Some of the Distinctive Tasks It Had to Perform in Serving the Army

ACCORDING to the manufacturers of metaphor, the war was a war of science, a war of food, a war of invention, a war of electricity, a war of nobody knows how many different things. We were told that the war would be won in a thousand different places, varying from the spruce forests of Oregon and the wheat fields of the Northwest to the trenches of France and Flanders. But in all this maze of statement and mild misstatement, one thing stands out pretty clearly: if you are going to wage war on the scale on which war was waged from 1914 to 1918, one of the very first things which you have got to put in order is the matter of transportation. Men and munitions and food have to be transported in numbers and in quantities that would have staggered the pre-war imagination; and the system by means of which this is achieved must function without a hitch.

The first chapter of modern transportation is of course the railroad. In a sense this is familiar to us all. We all have some idea of how the steam lines function, of the strain put upon them by a sudden influx of traffic of all conceivable kinds, of how this is met. Physically at least the railroad is well known. But war introduces a few complications before which we may well pause a moment.

The effect of the conflict upon the trunk lines of a nation, unless that nation be the invaded one, is easily dismissed by one word—congestion, unwonted congestion. This differs from the congestion of crop-moving or of any other period of overload only in the urgency of the demand that it be met and overcome. But the trunk lines are not the only face which the problem presents—not even in a case like Germany's, when they have been carefully mapped out in the first place, built and rebuilt with most meticulous care, for the very purpose of serving a war on the particular front where the war finally came.

The trunk lines bring men and supplies to the seaboard of a country like Britain or America that has no direct access to the fighting front; in a country like France or Germany, having such access, they approach to within a certain distance of the front. The distinctly military problem of military railroading is the making of that distance as short as possible, and the disposal of the supplies after they reach a point beyond which the trunk line may not penetrate. Since the front is seldom in a state of complete rigidity, but flows back and forth, there can be no permanent and inflexible arrangements for the distribution of soldiers and of freight beyond the base terminal created where the trunk line ceases. Lines must be built and rebuilt—a dozen times a day if the enemy is so fortunate or so skilful as to destroy them so often. Lines that can scarcely be distinguished from the trunk lines will be found leading out of the rail bases, to tail off gradually into more and more disreputable shape, until finally we come to the narrow-gauge tracks laid with practically no engineering preparation and leading, sometimes, actually into the trenches.

The war, by virtue of its unlooked-for duration, had one effect upon the railroads of the continental powers engaged which had not been sufficiently anticipated. This was the steady deterioration of track and equipment. The situation first became serious in Russia, without adequate means of her own for maintenance of her lines on a basis of efficiency; it was next felt in France, deprived of her normal supply of iron and steel; and finally it affected even Germany through the same shortage of materials. It became increasingly difficult to keep in running order enough cars

and above all enough locomotives to haul the traffic. The problem was met by improvisation and by the strictest economy in non-essential use of railroad facilities. Even so, the Russian railroads broke down altogether at about the time of her withdrawal from the war; while those of Germany were in such condition at about the same time that the business of transporting troops back and forth across the Empire to and from rest on the relatively tranquil Eastern front was seriously embarrassed. Where the shortage in Russia was felt in all lines of railroad supplies, that in Germany was more acute in lubricating oils than anywhere else, which of course meant that locomotives and trucks were subjected to many times the ordinary wear and had their useful lives proportionately cut down. The armistice found the German railroads at the point of collapse, while those of France had only been saved from a similar but earlier fate by the injection of fresh material from America.

WHAT WAR MEANT TO THE GERMAN RAILROADS

On the whole there has been little change in the technique of war-time railroading during the four years of conflict. It may, therefore, not be out of the way to give, as an account of the problems met and the solutions effected, an abridgement of the official German account of the rail operations of the Imperial Staff during the first nine months of the war. To be sure, this was prepared for the edification of the Teuton public, and may therefore to a certain extent suffer from the desire to "fly the flag;" but on the whole it is a trustworthy and an admirable account of what had to be done and what was done. This is what it tells us:

When war was declared in August, 1914, the citizen population away from home made a general rush to the railways in order to escape delays that might be expected to follow when the tremendous tide of soldiers and equipment set toward the fronts. Thousands of others rushed by the same routes to distant points to reach sons, brothers and husbands at the practice camps before they should be off to the battlefield.

Some of the divisions had to be sent to the western frontier through sections alive with manifold industries. Thousands of long military trains were needed. In order to prevent hopeless congestion while these trains were en route all of the stations along the lines had to be cleared of a staggering number of loaded and empty freight cars. Simultaneously with the advancement of these troops an equally heavy movement in railroad equipment was begun. Hundreds and hundreds of freight cars and coaches and scores and scores of locomotives made up in seemingly endless trains were pushed along to those sections of Germany where, according to careful calculation, the rolling stock would be most needed.

Then began the real mobilization. Millions of reservists were carried to their appointed rendezvous; and supplies and accouterment for the troops were brought up together with the wartime armament for the fortifications nearest the enemy. From those sections of Germany where horse raising is especially followed, trainload after trainload of these animals were taken to the places where they were required in order to bring the troops up to a wartime footing according to prearrangement. Likewise, immense quantities of livestock were similarly transported to the army canning factories; and from the very outset of this wholesale stimulation of rail service the mining districts began pouring out vast quantities of coal which were borne to the naval bases.

A few hours after mobilization had been ordered, the first troop trains were on their way to the fronts; and day by day this movement increased until the armies stood ready for service and magazines and other supply stations reached far rearward, according to previous plans, for the purpose of supporting the troops under all conditions. This efficiency was the immediate result of the work done in time of peace by the railroad division of the General Staff and its various associate organizations.

The skill of the officers in charge of the "railroad marching columns" undoubtedly contributed very largely to the German successes upon both the East and the West fronts; indeed it was due to them mainly that the Kaiser's forces proved victorious in their drive through Galicia. The flexibility of the railroad marching columns depends, in the first

place, upon a well-developed network of lines, and then upon a perfect understanding of the physical characteristics of those routes bred of a careful survey of them by the General Staff in times of peace.

HOW THE RAIL UNITS WORKED

The moment the German troops entered upon enemy territory the problems of the "railroaders" became many and various. The retreating foes dynamited bridges, blocked tunnels, destroyed rolling stock that could not be moved, and, as far as possible, tore up the roadbeds and effectually damaged the rails. It was of course necessary that the invading Germans should advance rapidly, and it was equally vital that the railroads should be restored and pushed along quickly behind the troops. In anticipation of just these tasks, two Military Railroad Organizations were detailed at the time of mobilization for this important work.

Organization No. 1 was in readiness at Aix-la-Chapelle for the advance into Belgium, and was the first in the field and among the foremost of the invading troops. Aside from minor damages, such as torn up rails, overturned locomotives and cars blocking the route, they found thirteen bridges that had been dynamited and a tunnel choked up by collision of a number of engines purposely run into it at full speed. Telegraph and telephone wires had been torn down and the operative plants of railway stations put effectually out of commission.

As in every other field of their service, the rail men toiled ceaselessly. It was not long before they achieved all necessary repairs and had the lines temporarily fit and, later, put them in first-class shape. Some idea of the speed with which these things were done on the Western front can be gathered from this official statement of operations: "On September 1, 1914, Military Railroad Organization No. I moved into Brussels, and at the end of October it pushed on through to Lille. Newly-formed organizations then took over the management of the restored roads and stations. On the 20th of August, 1914, Military Railroad Organization No. II was stationed at Ulflingen. On the 25th of August it had advanced as far as Libramont, and by the 4th of September it reached Sedan." As Organization No. II moved on it was likewise supplanted by newly formed railroad working forces as far as Luxemburg. The Western front finally reached such proportions that Military Railroad Organization No. III was created and its headquarters were established at Charleroi.

The railroad lines immediately behind the fronts were operated by the railroad troops, and linking up to these sections from the rear the service was maintained by the regular personnel of the German railroad system. This illustrates just how the peacetime and the wartime organizations were coördinated.

Following the first few months of the war, during which the railroaders were called upon principally to restore and maintain established rail routes, their work became that largely of building entirely new lines or of double tracking and otherwise amplifying existing roads. Where the German tracks stopped at the frontier it was necessary to extend them into the enemy country as far as military exigencies demanded. This imposed a great many difficult undertakings. During the winter when the ground was miry, highways dreadfully cut up, vehicular traffic well-nigh prohibitive, and the tracks of the rail lines in a bad condition, an extensive network of tramways or field spurs was built right up to the firing lines in order to bring forward ample supplies of munitions and provisions.

In place of temporary bridges, permanent ones had to be erected in course of time so as to bring up the service to a high state of efficiency and to insure safety for the heavy traffic. Again, in this work, the railroad troops did their part in the theaters of war, while private firms were called upon to do all the necessary engineering work of this sort in the rear. In nine months after the beginning of hostilities, 104 big bridges were constructed, eight tunnels rebuilt, and fourteen important main railroad lines restored to service. Besides these things, 160 railroad stations were enlarged by adding to their yard trackage and their facilities for loading and unloading freight. Further, numerous sidings, able to accommodate the longest of military trains, and many branches, connecting main lines, were laid.

MOTORIZING THE WAR

How the Warring Armies Got Through the Initial Stage in the Process of Replacing the Horse by the Motor Truck for Heavy Hauling

AFTER all is said and done, the railroad deals in transportation by wholesale. For transportation by retail it is fundamentally unfitted. Its cars are too large and involve too much rehandling; its motive power is too bulky and costs too much for starting and stopping; its right of way is too expensive for anything except permanent and well-travelled routes of considerable length. The ease with which the railroad carries bulk freight across the continent at less than the cost of handling upon arrival at the destination demonstrates that for wholesale transportation on land the railroad can have no rival. But the ease with which motor trucks and trolley cars, horse-drawn vehicles and bicycles, one-horse-shays and wheel-barrows, can transport small amounts of freight and small numbers of passengers over small distances at a figure and with a degree of convenience which the railroad cannot approach, proves that for transportation at retail the locomotive must be replaced by something else.

In all previous wars the agent of local transportation, the means by which the actual fighting units have been supplied from their immediate bases, has been the horse. When Napoleon said that an army travels on its belly—a remark as true to-day as when it was made—he probably had in mind that the belly in turn traveled a-horseback or in a rough horse-drawn cart. The army of to-day travels faster than this. It still travels on its belly, but the belly moves on motor trucks instead of horses.

Perhaps the most interesting example of motor trucks in this work is that of the Paris motor buses. With 500 of these vehicles transformed into meat wagons by boarding over the windows, 750,000 men were supplied with fresh meat daily. The load of each bus was made up of approximately 4,000 pounds of meat, which is sufficient for 3,600 rations of 1.1 pounds each. Although only one-half the number used, or 250, was considered necessary theoretically, the others were maintained to assure a regular service and to insure a margin of safety against all the unforeseen circumstances of war.

After the Paris motor buses had been in active service for more than twelve months, the percentage of failures due to mechanical troubles had been very small. This was due in a great measure to the fact that all these vehicles are employed in convoys with no other types and that the drivers were the same men who operated them in civil life on the Paris thoroughfares.

All these buses were in the army service one hour after the notice of mobilization had been posted at 4 o'clock on the afternoon of August 1st. Each driver completed the trip he was making and then drove directly to a predetermined point in the city where each vehicle was loaded with either men, ammunition or food for the frontier. This was done without hitch, for France has an institution known as the *Service du Train des Equipages,* which is fully posted as to the condition of every motor vehicle in the republic, its owner and driver. This information is all enrolled in the plans for mobilization.

THE MOTOR TRUCK IN THE FIELD

The armored motor vehicle, consisting of either a motor truck or a passenger car chassis carrying a light, small-caliber gun protected by thin sheet plating, has played an important part in the modern method of warfare. This was especially so in the fighting among the sand dunes of Belgium where speedy vehicles of both the Allies and the Germans made spectacular raids into the enemy's country, inflicting severe damage on the opponent's infantry

and then making a quick escape before they could be badly damaged.

Some of the German types weighed from eight to ten tons and were actually traveling fortresses with the guns, men and the vital parts of the vehicle itself protected by heavy steel plating. While these might have been of great value if the march to the doors of Paris had been carried out over the main roads in August as per schedule, they soon lost their effectiveness by becoming mired in the mud on the second-rate roads a month later after rain and frost had got in their work.

As a result, the extreme type of traveling fortress proved unsuitable for present war conditions and two new types were evolved. The first is a powerful touring car or a truck of two tons capacity, completely incased, but with the total weight kept as low as possible. The second is a four-wheel-driven truck of the same capacity but so arranged with drivers' seats and steering wheels on both ends that it can be driven from either end. When cornered on a road where it is impossible to make a turn quickly, the car can be run backwards out of danger's path at the same speed at which it can move forward. This type of armored motor truck, although comparatively new, was embodied in .the fast touring cars of smugglers that were used before the war in getting untaxed goods across the Franco-Belgian frontier.

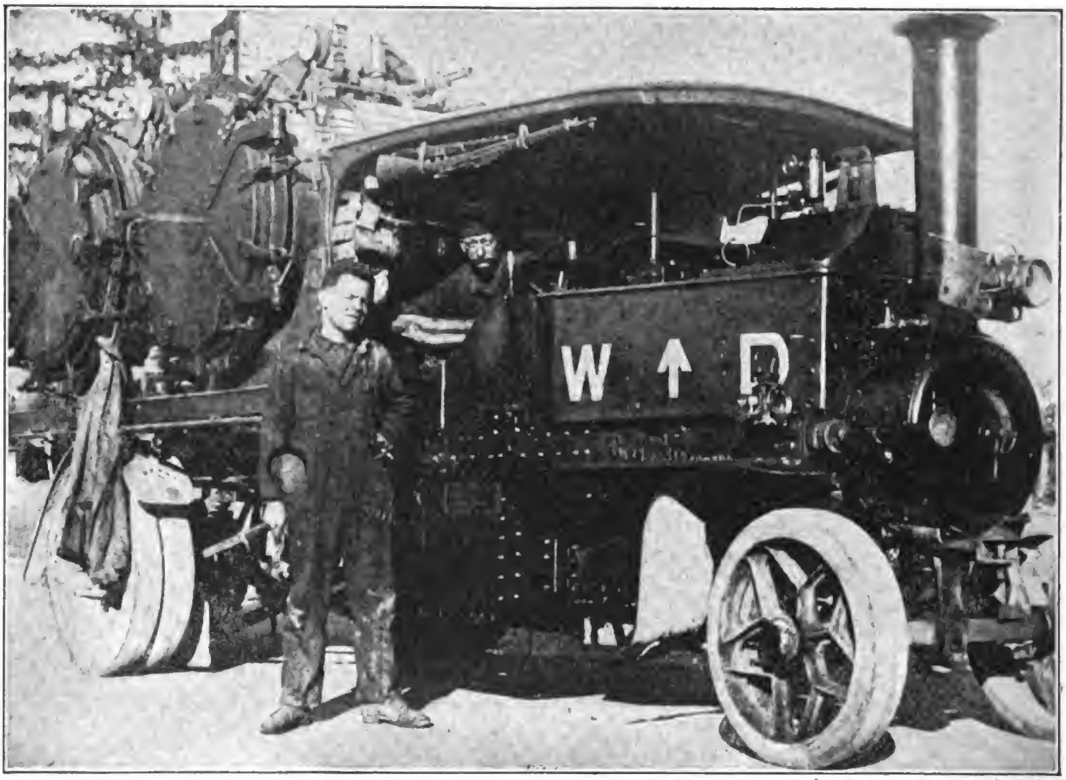
Courtesy of Scientific American.

Everywhere the Doughboy Goes, His "Chow" is Sure to Go

Here is a motorized kitchen unit used by the American Army with excellent results. A large steam boiler provides steam for heating the "chow" in the huge steam kettles, as well as plenty of hot water for all purposes.

Many thousands of trucks and passenger cars were used by both sides as ambulances. Some of the types used by the British Army consisted of heavy passenger cars or light trucks with a canvas body and mica windows on each side. Four to six stretchers may be placed in each body in rows of two or three, one above the other on each side, with a vertical aisle between. The physician or surgeon rides in this aisle and is thus able to watch all the wounded at the same time and to render any necessary aid. France also had a large fleet of vehicles of a somewhat

similar type of design. She also used many of the closed-body trucks returning from the trenches after having unloaded food or ammunition. Stretchers are slung from the roofs of these vehicles and while this method has the advantage of getting the wounded away quickly, it offers little in the way of comfort. of officers and members of the staffs and others with ambulance bodies for Red Cross work. To the above must be added perhaps a thousand or two trucks and passenger cars shipped to Canada and Australia which eventually found their way to the fighting line on either the Eastern or Western front.



International Film Service.

The Army Laundry

An American steam laundry using British apparatus close to the front lines. The big drums, filled with boiling water, cleansed the clothes of our soldiers.

EXPORT OF AMERICAN CARS

At the beginning of the war there were approximately 250,000 motor vehicles with the armies of the five belligerent nations, of which slightly less than 100,000 were trucks. Up to and including June, 1915, the Allies imported from this country 14,446 motor trucks of all sizes and valued at the tremendous sum of $39,230,282. Then there also were large shipments of passenger car chassis, amounting to 23,880 valued at $21,113,953 for the twelve months ending June, 1915, some of them with conventional bodies for the use

With these, the total shipments of both passenger cars and trucks exported from this country amount to approximately 38,000, of which about 15,000 were trucks.

Add to these 15,000, the 100,000 owned and commandeered by the five belligerents at the beginning of the war and approximately 5,000 more built abroad since the conflict began and we have approximately 130,000 trucks actually in service at the front in 1915! These trucks lined up in one long convoy, with the ends of each touching the preceding one, would form a line approximately 425 miles long.

THE MIRACLE OF THE MOTOR

How Verdun, Cut Off From the Railroads, Was Saved, and the Motor Truck Promoted to Play a Bigger Part in the War

THE outbreak of the war forced the armies engaged to fall back upon the motor truck in order to secure effective transportation. But certain it is that the full potentialities of this new vehicle—new, that is, to Mars—were not fully understood until after the Verdun campaign of 1916. In this campaign for the first time it was necessary to place absolute reliance in the motor truck for the entire supply of an important section of the front; the railroad that had been expected to supply Verdun was permanently out of commission. How the motor truck filled the breach is a matter of history, but one which must be rehearsed here as an important chapter in the progress of the truck from a mere substitute for the horse to a fundamental means of war-time transport, available for wholesale transportation as well as for retail.

To understand how motor trucks saved Verdun and why it was a miracle, one must first of all understand the position of the French at the famous old fortress and the strategy of the Germans in attacking it. Now Verdun was the weakest point on the entire line held by the French. Why? Because the quick demolition of the great fortresses of Liège, Namur and Maubeuge had demonstrated the utter futility of forts to withstand the fierce bombardments of this war, and because Verdun itself was a salient in the line, open to fire from the front and from the sides as well.

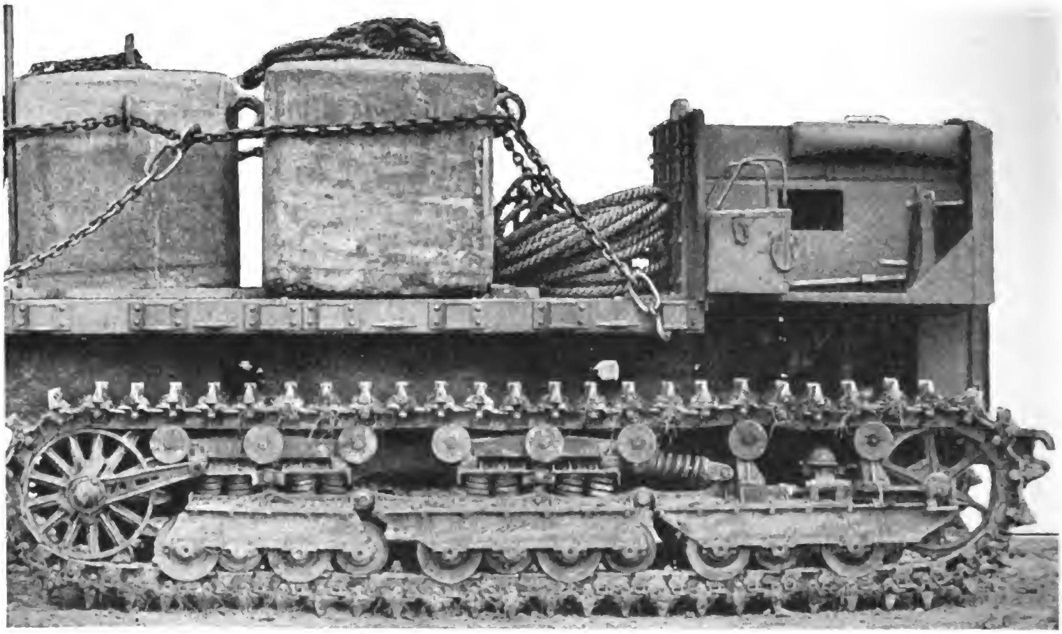
Besides, Verdun was the hardest point on the entire French line to supply, because it could not be reached by a single railway. It will be remembered that when the Germans took St. Mihiel in September, 1914, they cut the main railroad supplying Verdun, the Paris-Nancy line. After their retreat from the Marne they continued to make its use impossible by reason of their long-range guns set up at Varennes and Montfaucon. In consequence, the French were at first compelled to use a single-track, narrow-gauge line running north through Bar-le-Duc, which was entirely inadequate to supply the needs of the defending forces because of its grades and the slow service which it offered. Under these conditions Verdun was practically isolated because it could not be served by railway.

So long as Verdun was defended by a relatively small force, the bringing up of food and ammunition was a comparatively simple matter for the motor truck transport. But it became a tremendous task indeed when the Germans at the beginning of the attack massed a quarter of a million men and more than two thousand guns on this narrow front. In fact, it was such a tremendous task that General Joffre favored the evacuation of Verdun because of the great sacrifice its defense would entail. That Verdun was not in this way given up was entirely due to political pressure brought to bear on the military. It was here, then, that the motor transport performed its miracle of bringing up a quarter of a million men, supplying this great force with food and ammunition and removing the wounded. It was the first time in the history of the World War that any army of this great magnitude was dependent entirely upon motor transport. It must be remembered in this connection that the amount of ammunition expended by the French in the defense of Verdun was greater than that used in any previous battle in the world's history, not even excepting the previous year's French offensive in the Champagne. It is indeed a miracle that motor transport was able to supply every single shell, in addition to bringing up a fresh army of perhaps more than a quarter of a million men, its rations, supplies and innumerable guns both heavy and light.

The first problem of General Herr, in com-

mand of the forces at Verdun when the attack began, was that of roadways. He foresaw many months in advance the great handicaps the motor transport would be under in case of an attack on the fortress, and at once began the entire reconstruction of the one main highway running south from Verdun through Bar-le-Duc and St. Dizier. This road, at first, like the other average roads of France, fairly narrow, though with a good foundation, would not have been sufficient to prevent congestion and delays, costly if not fatal, when several thousand motor trucks had to run over it in both directions at the same time.

Accordingly, this road was entirely rebuilt. Army engineers laid down a new foundation, doubled its width in some places and tripled it in others. Turnouts were provided at certain specified intervals, on which trucks not working properly could be sidetracked and their troubles remedied. In every village along the route there were repair shops complete in every detail, filled with every conceivable part that might be needed to enable a damaged or broken-down truck to regain its position, and equipped with everything in the way of machinery and tools that would permit such repairs to be made in the minimum of time. These stations were to be operated by details of experts, men who had made it their profession to know motor trucks and how to repair them without bungling and who could get them to work in the shortest possible period. Way back in the interior of France, thousands and thousands of motor trucks were held in readiness for the expected attack—some were to carry beef and rations; others nothing but ammunitions, and still others supplies and guns, guns of all sizes and descriptions—while all were to do their share on their return trips in rushing to the base hospitals those of the wounded who had any chance of recovery.



A Tractor Motor Truck

With these preparations made, it was simply a matter of giving orders and of superintendence, but a tremendous job at that, to set this marvelous motor transport organization into operation once the attack was begun and the decision to defend the fortress was made.

For more than fifty miles back of Verdun the newly-built highway, out of range of the German guns at all points, was filled with a long procession of trucks, described by those who saw the work as a continuous stream or torrent more than a line of vehicular traffic. The preparatory organization was so perfect

© Paul Thompson.

How the British Were Fed on the March

A form of field oven used while on the march so that a hot meal was ready as soon as the troops reached camp.

and the condition of the trucks so perfectly attended to that there was scarcely a break in the snake-like procession whch moved forward with clock-like regularity. Advancing with their capacity loads, the vehicles discharged their burdens at predetermined points behind the front, whence the material was carried to the trenches by one- or two-horse carts. The return, empty or with wounded, was made like the advance, with the same military precision. All day and all night these great trucks ran, uninterrupted. They proved the salvation, the miracle of Verdun. They demonstrated that the motor truck could meet any demand made of it by wartime transportation necessities.

HOW THE TRUCK CAME OUT OF IT

The Liberty Model of the American Army, Climax of Three Years' Experience in the Field and the Factory

IF the motor truck made modern warfare what it has turned out to be, it is no less true that the war resulted in very distinctive types of trucks designed especially with the view to military use. All the nations in the big fight had these. It is out of the question to attempt a description of all of them. But the American truck was the last to come out, and in it were incorporated the results of all the lessons which the Allies had learned. So far as the experience of the World War can dictate, it is the war truck par excellence. It is therefore appropriate that we pause for what may turn out a somewhat technical account of this truck. And first of all it is in order to say a word about its genesis and history.

The story of its design is as simple as it is inspiring. High salaried representatives of the leading automobile, engine and parts

manufacturing companies were called together by the Society of Automotive Engineers, told one story and asked one question.

"The success of modern war depends on no one factor more than upon successful, speedy, economical and certain transportation of supplies. Other things being even approximately equal, the Army with the best transportation wins."

That was the story. Follows the question:

"You gentlemen, together, know more about trucks, engines, and parts than the rest of the world put together. Are you willing to sink personal pride and prejudice, are you willing to forget trade and money making, are you willing to pool your knowledge and make for the government a standardized truck

Courtesy of Scientific American.

A Motor Truck Equipped with an Apparatus for Crossing Trenches

which will be to all other trucks as the racing car to-day is to the racing car of ten years ago?"

HOW THE LIBERTY TRUCK WAS CREATED

"Very simple," was the answer. It was a universal assent, followed by conference after conference, design after design, labor after labor. Engineers who had not done more in detail than think and direct for years, bent over drawing boards, cross-hatching. Designers who had hitherto guarded the secrets of their plans with locked doors and trusted employees talked freely to their competitors. One engine maker who had designed a combustion chamber, tested it and perfected it and found it something ahead of all others and who was planning to use it on 1919 or 1920 cars handed it over without a thought. Every man with a pet oiling system brought it to conference and puzzled over the fact that the others were as successful as his whether it worked at 100 or fifty or twenty or two pounds pressure, until experiment and calculation showed that all were successful because all were passing the same amount of oil per revolution regardless of pressure. Rear axle men forgot the rival claims of their respective companies, freely admitting the other fellow's good points, and together produced a rear system which combined the best of all. Lubrication, ignition, governing, transmission, cooling, springs, weight distribution—all received the attention of the men who made the best in the world, and were designed, not by one, but by the cream of the profession.

The net result of all this was one truck for the American Army, than which no other model was supplied to any army organization after January 1, 1918. What this means, even were the truck just an ordinary vehicle, only those who have worked out transportation problems at the front may know. In Paris a huge twelve-story building, filled with card systems and hundreds of clerks, cared for the stock of over 2,000,000 different *kinds* of parts required to maintain *all* forms of motor transportation on the Allied fronts. *One* maker in England makes seventeen different varieties of trucks and the English use all seventeen. Of course, there are hundreds of kinds of trucks in use, and all must have spare parts ready, somewhere.

There are approximately 7,500 parts in the U. S. War Truck and, if the Army possessed a million of them, there would still be only 7,500 *kinds* of parts to carry for repairs and replacements. There is nothing left to argue about.

THE LIBERTY TRUCK

The new Military Truck, popularly the Liberty Truck, while exceptionally strong and powerful, is of conventional design. It embodies all the modern ideas tried and proved in service, which means that no detail is experimental. The wheelbase is 160 inches. The engine has four cylinders $4\frac{3}{4}$ by 6, with 424 cubic inches piston displacement. Transmission is a four-speed, amidships clutch, dry disk inclosed; and the rear axle is a worm drive, full floating type. Steering is by worm wheel, fuel feed by gravity from a 15-gallon tank on the dashboard, with a 16-gallon re-

serve tank under the seat. Double ignition with battery and magneto system entirely separate makes for reliability.

A straight frame of pressed steel channel section rests on almost perfectly flat springs. Brakes are integral and on the rear axle. The design has unusual strength for its load capacity. Really a five-ton truck, it weighs 8,000 pounds without body.

It is hard to conceive of a better designed engine. Three points had first attention; first, the best possible lubrication; second, a water jacket reaching every hot point; and third, rigidity without excessive weight. An entirely enclosed governor of great simplicity cannot be tampered with when once set. Cylinders are cast in pairs with detachable heads. Spark plug pairs are located side by side, with a water space between bosses, in the center of cylinder.

As an example of careful detail, the water outlet pipe is offset to allow easy access to both plugs with a socket wrench. All the combustion space is in the head castings, the tops of the blocks being faced flat. Valve ports, 2⅛ in the clear, are tungsten steel head and stem, with 60-pound springs. Intake valves are restricted to 1 11/16 inches at the flanges, to maintain a fairly high velocity up to the moment of entering the cylinder.

Crank case is all aluminum including the bell housing and pan. At the rear two deep arms act as rear supports. The diameter of case and flywheel housing makes these arms extremely short and they are so formed that the top of the bell makes a complete arch construction. The front support held in a swivel collar on a dropped cross member of the frame gives a three-point support with sufficient flexibility to counteract all stresses.

Complete pressure lubrication is used. Even the wrist pins are fed by tubes secured to the connecting rods. The pump and well are separated from the rest of the system by a wall which prevents falling oil from entering without passing through an elaborate screening system. Forward the pan is shallow, giving great clearance over the front axle, sloping to the deep rear end which contains the oil. A deep settling chamber catches all particles of carbon and impurities, preventing them from passing into the main oil reservoir. In addition, a large screen of wire mesh and still another on the pump intake makes oil circulation go from pump to bearings to settling chamber to first screen to second screen, and then around again. Draining the settling chamber does not affect the main body of the oil, so very little need be wasted.

Valve tappets are housed individually in the crankcase. Timing is as follows: Exhaust opens 45 degrees early, closes five degrees late, intake opens 12 degrees late, closes 25 degrees late. A skew gear on the rear end of the shaft drives the oil pump shaft. The pump shaft is vertical and coupled to the pump by a short coil spring. Both drive shaft and pump shaft are slotted and the two ends nearly meet the bent-over extremity of the springs setting in the slots, allowing the oil pan and the pump to be removed and replaced with a minimum of trouble.

On the right side of the engine are the generator, the carburetor and both manifolds. On the left are the water pump, magneto and battery ignition distributor, the latter set on top of the front end case, driven by skew gear off the water-pump drive-shaft. This makes for ease in linking together the magneto and the timer advance controls, and keeps all wiring on the one side of the engine.

The governor consists of steel balls held between a disk, sliding forward against a spring, and a female cone fixed to the camshaft. The disk bears upon the short end of a vertical lever, the upper end of which is linked to a throttle in the intake manifold. This lever is fully enclosed and the spring which pushes against the centrifugal action of the balls is set in the case halfway up the lever.

Pressure on the spring is set by a threaded plunger with a lock nut secured by a sealed wire, entirely preventing unauthorized adjustment.

Water pump is a separate assembly, its shaft coupled to the drive shaft. It is detachable without disturbing the front end. The magneto, back on the left side, is coupled to the pump shaft. Clearances are large, and no accessory is placed awkwardly. The crankshaft is 2½ inches in diameter on the three main bearings and 2⅜ on the pin.

The flywheel is 20 inches diameter and four inches wide on the rim, the weight being

130 pounds. The cast-iron pistons are 6⅛ inches long with three rings and a 1⅜ hollow wrist pin locked in position. Ten thousandths clearance at the top and over the upper ring is called for, and four thousandths on the lower ring and the rest of the skirt. The manifolding system, designed for heavy gasoline, is the most experimental thing about the engine.

The carburetor, vertical, is set high. The multiple dry-disk clutch of 18 plates is completely enclosed in a bell housing, and detachable from the flywheel in practically the samr way as a unit power plant. The aluminum casting embodies a platform to which gear lever and hand brake control unit is bolted. The clutch has a reasonably heavy pedal action and the throw-out bearing is unusually large to give great durability. Between clutch and transmission is a short universal shaft.

The transmission gives four speeds, with direct on high; the lowest gear ratio (allowing for the 9½ axle reduction) is 56 to 1. Provision is made for attaching a winding gear to the side of the transmission if required. The case is aluminum, and clutch and transmission together weigh about 300 pounds.

The transmission is so ingeniously hung that to remove it, it is only necessary to remove a cap, knock out two pins at the rear, after disconnecting the pins in the three-gear shifter rods, and disconnect a universal joint.

The propeller is normally horizontal, in a practically perfect position for the drive. The axle, though it contains much that is ultramodern, is in exterior appearance of standard construction. It is a full floating pattern with a pressed steel case and has taper roller bearings all through, even to the worm shaft. Both sets of brakes are expanding, side by side on the same drums, of the band type and provided with adjustment for setting concentrically. In laying out the brake connections, great care has to be taken to plot the path of the brake lever eyes as the spring deflects. The two cross shafts are placed so that the axle movement will have a minimum of effect upon the brakes to compensate for torsional deformation of the spring. The axle brake levers are carried up till the eyes are nearly in line with the top plate of the spring. Thus spring deformation causes an up-and-down movement of the levers instead of a horizontal one, and the vertical movement does not affect the tension of the brake rods.

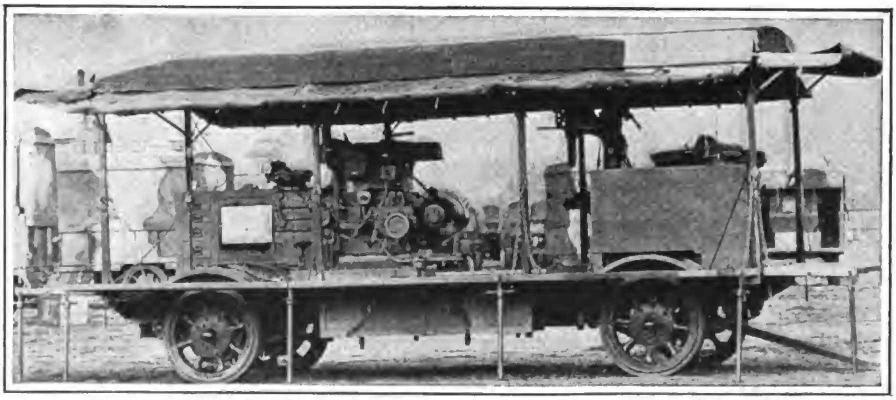
THE MOBILE REPAIR SHOP

How Machines and Mechanics, on Trucks and Trailers, Follow the Army into Action and Keep All Equipment on the First Level of Efficiency

THE motor truck was designed in the first place for transportation of goods, just as locomotive and passenger car were designed originally for the transportation of passengers. But just as we have dining and sleeping cars which combine transportation with necessary service, just as we have refrigerator cars and post-office cars to make certain other kinds of service transportable, so we find in the Army a great variety of truck outfits whose purpose is to give wheels to the commissary or the hospital or some other equally essential non-combatant branch—with its tools. There are repair trucks of every imaginable description, there are laundry trucks and lunch trucks, motorized kitchens and trucks that carry a fully equipped dental laboratory, shoemakers' trucks and trucks mounting a complete electric generating plant, trucks to keep the other trucks in working order—there can hardly be any cataloguing of the vast variety of trucks necessary for the proper support of the modern army. So instead of trying to catalogue these, we shall content ourselves with a description of one of the auxiliary truck outfits—the one that carries the wherewithal for keeping the big guns at the front in first class order. It will be understood that this outfit is merely typical—that every other branch of the service was equipped with as complete a traveling re-

pair division as the one whose operations we are about to describe.

Another general remark is in order here, pointing out the extent to which the trailer is used in all such service. If you mount your machine shop on the motor truck proper, you have a distinctly restricted space, and you are at the mercy of accident. Anything that puts the truck out of commission puts the repair outfit in the same hole. If you use trailers, on the other hand, you can use as many as you please, and thus escape all limitations of space; while the worst thing that an accident to the motive power can involve is the sending for a fresh truck and the hitching of the trailer to it. So in general, much of the mobile repair equipment is mounted on specially designed trailers, hauled by the *standard* army truck.



Courtesy of Scientific American.

A Type of Mobile Repair Shop Which Was Used Extensively in the Army

WHAT THE MOBILE REPAIR SHOP CAN DO

When an ordnance repair shop is able to take captured guns and put them in condition to be used against their former owners as they retreat, such an achievement would seem to entitle the mechanical part of an army to rank but little after the actual combat troops. This was the record of the 2d Mobile Ordnance Repair Shop of the American forces on the Soissons front when its personnel made ready for action against the retreating Germans 28 cannon captured or abandoned, and ranging from 77 mm. to 210 mm. guns. Similarly the mobile ordnance repair shop attached to the 35th Division had a record of having no piece of artillery out of action longer than five minutes during the Argonne drive. In fact such work enabled the American Army to have 97 guns on the firing line to three out of action, and contributed in no small measure to the efficient execution of the artillery program.

Whatever may have been the lack of preparedness of the United States Army as regards arms and munitions at the outset of the war, once the huge ordnance program was put under way, there was not the slightest delay in providing equipment to maintain at highest possible efficiency the artillery, motor vehicles and other appliances at or near the firing line. It was realized that battles might be won or lost by the number of guns ready at any time to function with maximum effect. Accordingly the Ordnance Department, along with the construction of artillery, organized a comprehensive scheme whereby the guns, howitzers, and mortars always would be attended by ample facilities for the immediate repair of greater or less mishaps.

The idea itself was no new one for the American Army. In the operations on the Mexican border the ordnance and artillery officers realized that there must be available facilities for the repair of the small arms and machine guns and equipment as well as light guns and howitzers, and particularly for the motor trucks and tractors then beginning to be used. No time was lost in attacking this problem.

TRUCK UNITS THAT KEEP THE GUNS IN ACTION

Experiments and studies made on the Border and at Rock Island Arsenal led to important developments and innovations available when the United States entered the war. All of this was along the ordinary lines of the American service, but the ideas needed considerable enlargement as the European war progressed. Mechanical traction and mobile mounts were applied to artillery of such size as never before had been fired except from permanent emplacements, with mechanical devices larger and more complex than ever before had been attempted with field artillery. All of the guns and howitzers with their breech, recoil, and training mechanism, while robust in construction, nevertheless had parts accurately fitted and of such delicacy that failure either in some adjustment or element was possible and might put the piece out of commission, which an available spare part replacement or repair would prevent. So supplies and spare parts, lathes, drill presses, milling machines, shapers, oxyacetylene welding and cutting outfits, riveters, forges, and in short all the various tools of a machine shop that could be used without a permanent foundation were transported mounted on motor trucks or trailers together with suitable cranes to dismount and handle cannon and carriages. Inasmuch as modern artillery is now so completely motorized the mechanical problems of truck and tractor engines and chassis are added to those of the guns and carriages, while the tank and various other tracklaying vehicles also require extensive repairs and replacements.

The first and simplest unit on the repair program is the light repair truck having a special steel box body on a ½-ton chassis. There is a single seat in front and chests containing carpenter's and machinist's hand tools are carried, along with automobile tools and supplies, lubricants and greases, so that the equipment with a skilled mechanic is available for light emergency repairs and general utility work beyond the facilities of the ordinary equipment and personnel of a battery or other organization. These light repair trucks were furnished to heavy motorized artillery regiments, motorized machine gun battalions, mobile ordnance repair shops, ammunition trains, army and corps artillery parks, and the trench mortar battalion attached to a corps.

The next item is the so-called ammunition truck, a motor vehicle with a four-wheel-drive type of chassis and a special steel body, which, while designed to accommodate the original packing boxes of ammunition, can carry any supplies or equipment needed, including drums of gasoline or water. The ammunition truck is used as a road tractor for hauling artillery or trailers of various types described later.

The artillery supply truck, also motor driven, consists of a specially designed body mounted on a four-wheel-drive chassis of either two or three tons capacity, and naturally plays an important part in the repair shop scheme. It carries spare parts for artillery and motor vehicles, extra wheels, tools and supplies, cleaning and preserving materials, and chests for tools and other articles such as the spring chest, supply chest, forge chest, fluid chest, etc. There are five different arrangements of loads depending upon the nature of the organization to which the supply truck is issued. In some of the trucks there is space for parts of optical and electrical instruments, and raw material and bar stock are carried.

The equipment repair truck, able to perform actual repairs on machine guns, small arms, saddlery, and personal equipment, is attached to division and corps shops and to each heavy artillery mobile repair shop. A four-wheel-drive motor-truck is made on which a special body is placed, the sides of which let down to form working platforms. This body contains a series of steel chests, cabinets and drawers, and work benches, on which are mounted sewing machines for canvas and leather, four vises, and a hand-operated emery wheel grinder. There are also complete sets of carpenter's and saddler's tools.

MACHINE SHOPS ON WHEELS

The most interesting and self-contained unit of the repair shop is the artillery repair truck, which like other elements is mounted on a four-wheel-drive motor-truck chassis and is a very complete small machine shop, as will appear from a summary of its equipment. This includes a 9-inch motor-driven lathe, bench type, with milling and gear-cutting attach-

ment; a 14-inch motor-driven drill press; a 12-inch motor-driven emery-wheel grinder; portable electric drill; oxyacetylene cutting and welding apparatus; electric motor-driven air compressor with air reserve tank; pneumatic riveting hammer; blacksmith outfit, including standard ordnance forge; and a complete assortment of tools necessary to repair artillery matériel and motor vehicles. To supply current for lights and for operating the machine tools there is a four-kilowatt generator which is direct-connected to a four-cylinder gasoline engine mounted on the floor of the truck. The sides of the steel body drop to form additional working space, while, as in the case of the equipment repair truck, there is a canvas cover and sides.

Each artillery repair truck is accompanied by an artillery supply truck with bar stock and other raw materials used in making repairs. The artillery repair truck is supplied to motorized artillery organizations, one repair truck and one supply truck to each battalion; to ammunition trains, corps and army artillery parks, railway mounted artillery regiments, mobile ordnance repair shops, and the trench mortar battalion in the corps, according to the tables of organization.

From the various units described the mobile ordnance repair shop is organized and one of these is attached to each division. Normally it consists of six artillery supply, three artillery repair, three equipment repair, three ammunition, and two light repair trucks. Each of these units is motor propelled, and the tool equipment and personnel of trained ordnance mechanics is such that most of the necessary repairs can be made at or near the front without sending the guns back to the base repair shops.

But even more extensive and heavier work can be done in a larger and more adequately equipped organization, the heavy artillery ordnance mobile repair shop, whose equipment would be the equivalent of a considerable machine shop, but mounted on motor trucks and trailers and capable of following an army wherever roads permit the passage of large trucks. Such an organization consists of headquarters with two vehicles for the personnel, and two sections each consisting of 35 vehicles for men and equipment. In each section is a machine gun car for the personnel, 16 trucks of various types carrying machinery and supplies, 12 trailers drawn by the trucks and having various loads, a four-ton crane, a kitchen trailer, and four motorcycles.

One of these shops was designed for each brigade of six-inch guns and heavy howitzers of army artillery, this latter, it may be said in passing, being independent of the corps artillery.

As indicating the extensive scale on which these shops were planned, it was stated that by July 1, 1918, material had been ordered for 24 heavy artillery mobile repair shops. Their completeness may be realized from the following outline of some of the more important units. One three-ton truck, which like the others is fitted with the standard artillery repair body, contains a complete gasoline-engine-driven two-cylinder air-compressor unit and complete equipment of pneumatic tools, such as riveters, hammers, drills, and grinders. A second truck is used as a tool room, containing such small tools as drills, precision instruments, reamers, tool holders and different attachments, a key-bitting machine, two-wheel high-speed grinder, and a combination tool and cutter grinder. Another three-ton motor truck carries a 24-inch circular saw to rip wooden beams eight inches square and also a heavy automobile arbor-press large enough to press hubs into wheels or similar work. Six motor trucks carry spare parts or complete assemblies, such as motors, transmissions, etc. Two three-ton trucks carry the personal baggage of the organization, while one truck of similar size is fitted up as an office.

The group also includes a standard equipment repair truck with full complement of tools and equipment, an ammunition supply truck for carrying oil and gasoline in drums, an artillery supply truck with bar stock and raw material, and a one-ton delivery truck.

These trucks are accompanied by 13 special four-ton trailers to which are supplied a rectangular body with hinged sides, fronts and tailboards, and an adjustable top and canvas cove. These trailers carry the machine tool equipment of the shop, which includes a 2-A universal milling machine, nine-inch and six-inch bench lathes, sensitive drill press, 16-inch shaper, 22½-inch drill press, 18-inch by 10-foot engine lathe, small arbor press, all of the above being motor-driven from the shop power

plant. This is installed on a trailer and comprises two direct-connected gasoline-engine-driven generators, each of 15 kilowatts capacity, which supply power for the various machines as well as current for electric lights on all the trailers, for night repairs must be provided for.

There is also a trailer equipped with oxy-acetylene welding and cutting apparatus and a complete blacksmith equipment and arc welding outfit. Six trailers are equipped as parts stockrooms, one being furnished with a bar-stock rack and hacksaw. The heavy baggage such as the tents and the rations is carried in a trailer with a plain body, while a standard quartermaster type of kitchen trailer is also provided.

The equipment indicates the general nature of the work that the heavy artillery ordnance mobile repair shop can handle and its general usefulness. Of course guns cannot be relined, but many extensive repairs to breech blocks, and carriage mechanism, as well as to the various tractors and tanks, can be accomplished, making it unnecessary to send a piece or vehicle for a long road or railway journey over congested lines of communication to the base ordnance shops in the rear. The four-ton crane permitted the dismantling of cannon and the handling of the heavier parts.

THE MILITARY ENGINEER

The Problems That Confront the Man Who Is Called Upon to Lay the Foundations for the Army's Advance

IN a sense, everything described in this volume is an engineering development. The science of shooting high explosives at the enemy requires men who have devoted their lives to the study of explosive compounds, and who can accordingly lay claim to the title of "explosive engineer." The designer and the constructor of artillery, and the ballistician who gives then the data on which to base their work, and the metallurgist whose business it is to supply the right metals for guns and shell, and even the meteorologist upon whose study of the air are based the trajectories which the ballistician plots, are all engineers. Gas warfare, both offensive and defensive, is in charge of a corps of chemical engineers. Aviation calls for a miniature army of engineers with special identifying prefixes—airplane engineers, balloon engineers, men whose life work is the study of the action of fluids (i. e., air) and fluid pressures, above all internal combustion engineers to supply the motive power. A fresh crop of the latter is required for the solution of the vast problems of motor transport—problems so specialized that, to give but one example, the manufacturer of a leading magneto maintains a fairly large staff of men who would feel very badly if we should refuse to recognize them as exponents of the distinct profession of ignition engineering. And so it goes, *ad lib.* Even the doctor is a sanitary engineer when he works in groups and with the authority of the Army behind him; while the electric engineer must select from a multitude of subdivisions according to whether he would pursue radio or telephone or telegraphic work, power generation or transmission . . . the list is endless.

GEOGRAPHY AND WAR

For all that, we still have with us the man to whom the tacticians of a hundred years ago had reference when they used the word "engineer." He is, in fact, what we now characterize more fully as the civil engineer. He builds bridges across the water and digs canals across the land. He drains the swamp and converts dry land into a lake. He cuts down mountains and digs tunnels through them and builds roadways over them. In a word, the civil engineer does not deal with specific forces, but simply changes the surface of the earth to accord with the necessities of man. In doing this he is certain to meet with some problem that under ordinary circumstances would

be referred to a specialized kind of an engineer in some special branch, but which he has to solve on the spur of the moment. Accordingly he has a smattering of engineering knowledge in all branches, and is in fact the technical jack-of-all-trades. We would never think of asking the chemical engineer to set up a radio station, or demanding that the radio engineer fix up an automobile engine so that it would run again; but either of these jobs must of necessity fall within the capacity of the civil engineer. And in war, the civil engineer is the man to whom we look to make it possible for us to attack or defend where we should not otherwise be able to attack or defend.

Thousands of years ago this sort of thing was not done. The natural contour of the ground controlled and one had to give battle where geography dictated. One invaded Greece through Thermopylæ, and attacked Persia over the plains of Arbela. Centuries later, even, if one wished to fight out the destinies of Europe, one did so on the level plains of Belgium and France. But to-day Mars is not so confined by Dame Nature; he carries his business where he will, and if it is not convenient to fight where he elects to fight, it becomes the business of the civil engineer to make it convenient, or at the very least possible.

The first thing which the successful military engineer has to know is how to put down a bridge in a hurry—and under hostile fire. Indeed, the problems of the civil engineer are very largely imposed upon him by the necessity of putting water where it is not, or removing it from where it is, or at least of rendering its presence ineffective. The first pontoon bridge on record is the gigantic affair with which the Persian bridged the Hellespont; and his methods have not been greatly improved upon by his successors. A line of boats with planks laid over them—that is the soldier's bridge, and always has been; the only new features have to do with the ever-increasing difficulty of laying it in the face of hostile fire that gets ever more effective from war to war.

FIGHTING THE MUD AND WATER OF FLANDERS

The military engineer is not through with water when he has shown us how to cross a stream in the face of the enemy. Indeed, when we insist upon fighting in any such country as the low-lying Flanders coastland, the pontoon bridge represents about the least of his troubles, because the country is so largely given over to water that there are no individual streams for him to bridge. His task is now to make it possible for the army to live and operate in the sea of water and mud which confronts it.

So much has been written about the various offensives and engagements that went to make up the four-year-long battle of Flanders, that the very mention of this word suggests mud. Every report from that front tells of the struggle of the soldiers with the thick, sticky clay which is so characteristic of this terrain. The Battle of Flanders might well be called the Battle of Mud; after all, mud was the main concern of the British and French troops, since a preponderance of artillery automatically took care of a significant portion of German fighting spirit.

Where the terrain is dry and firm, modern fighting is largely a matter of intense artillery preparation, followed by carefully coördinated barrage fire and infantry assault. But where the terrain is a bog, the infantry, irrespective of the artillery preparation, is at a tremendous disadvantage. In some instances the British infantrymen in Flanders were unable to keep up with the methodically advancing barrage curtains, with the result that casualties were more severe than warranted by previous experience. Correspondents have told us of the British infantrymen sinking to their hips, and even to their neck, in mud, and of companions being obliged to pull some less fortunate Tommy out of a sinister mud hole. Indeed, in walking over this terrain the infantryman lifts one leg high into the air, and after placing it again on the ground he does the same with the other. The procedure, at a distance, resembles a form of dance, which is all the more pronounced when the men sway slowly from side to side, as they must do, to free themselves from the sticky mud.

Aside from the fact that the soil in some places is naturally sticky, the deplorable state of the Flanders terrain was largely due to concentrated shell fire. The churned earth, with its many shell holes, served to hold such water as came in contact with it; so that every

rainstorm—of which there were plenty—left the countryside a veritable sea of mud.

Besides being sticky, there is a far greater difficulty presented by Flanders mud—more than that, a positive danger—in the very softness of the ground. There is no firm footing to be had, and men and equipment sink deep into the mire. In some instances men drowned in the mud before help could reach them, especially at night when in utter darkness infantry made its way over miles of bog to the actual battle line. Much equipment, particularly boots and other footwear, was lost in the Flanders mud.

A most effective means of combating Flanders mud is presented in the so-called "duck board," used by the Allied troops in preparing approaches to the front-line positions. Duck boards are nothing more than short lengths of board walk which can readily be carried by the infantry and engineers. Because of the extensive surface which they present to the muddy terrain, the slatted walks do not sink and therefore offer a firm, solid footing for the soldiers. Mile after mile of duck-board paths were laid behind the Allied line in Flanders; and as a daily diversion the German artillerists endeavored to locate and destroy these causeways over the sea of mud.

Aside from mud, Flanders is remarkable for its numerous brooks, creeks, canals, rivers and other waterways. Practically every Allied offensive meant crossing one or more of these diminutive waterways. For this purpose there were introduced novel pontoon bridges that took the place of the usual heavy structures, and that were of ample capacity for the use of infantry only. French engineers, in particular, developed two kinds of light-duty pontoons, one consisting of a number of thick layers of cork strapped to a simple wooden framework, and the other comprising chicken netting filled with broken cork, also held in place in a plain wooden framework. In the usual manner, these pontoon units were lined up and a walk, consisting of slatted flooring, laid across them. The convenience of these light-weight, inexpensive pontoon bridges is at once obvious when one compares them to the heavy, expensive boat units used in spanning a wide river.

There was, of course, no possibility of draining these flat lowlands. Drainage is not automatic; it depends upon the presence of a low place into which the water can be induced to flow off, or of a high place to which it can be pumped and in which it can then be safely confined. Flanders presents neither of these features; one might as well try to drain one half of a table top on to the other half as to attempt the drainage of Flanders by any method short of building a dike and pumping the excess moisture out to sea. But after all, this state of affairs carried one advantage, at least; for it made it certain that neither army would try to drown out the other, since the flooding of the territory occupied by the enemy would inevitably result in flooding that occupied by one's own troops. It was for this reason that the extraordinary spectacle was presented of two armies facing one another in a four years' deadlock across a half-drowned ruin of mud and water, unable to do anything beyond making existence as comfortable as possible on the right side of the dividing line and as uncomfortable as possible on the wrong side.

EMERGENCY RAILROAD WORK

In more favorable country, where considerable advances are feasible, the engineer is confronted by different problems. The matter of the pontoon bridge is one of immediate attack; but his interest in advance and retreat does not stop here. In advance, after the new ground has been won it must be "consolidated" —made an integral whole with ground previously occupied. This means the building of roads and railways and the replacement of pontoon bridges by more permanent structures. In retreat, on the other hand, it is necessary to do as much damage to the terrain, and especially to the channels of traffic, as possible, so as to hinder the work of the engineers of the advancing foe.

The latter, in turn, must then be proficient in restoring order out of chaos. It is truly surprising to what an extent destruction intelligently carried out on an organized scale by a group of engineers goes beyond the most thorough wreckage of which a less informed agent would be capable. Nor is it by any means the case that the mode of destruction involving the most labor is most effective or most permanent. The Russians, past masters in retreating through wide practice in this

and earlier wars, have brought destructive engineering to perfection. A method to be effective must be quick and simple, as very little time elapses between the departure of the last train and the arrival of the enemy's advance guard. Their system is simplicity itself. A dynamite cartridge is bound to every rail joint and exploded. This either breaks the rail off at the fishplate or bends it out of line an inch or so. A small matter but just enough to make it impossible to use the rail again till it has been sent back to the mill and straightened. One American traveling with the Teuton armies in the Galician campaign saw hundreds of miles of rails thus rendered useless in Poland and Galicia.

The Russian track is of a gauge about a foot wider than the German, which is the standard continental. Hindenburg at one time decided to retreat out of a certain district. In advance of this movement he had all the railroad ties taken up and cut off so that they were just long enough for the German standard gauge track but too short for the broad gauge Russian. The Russians had to take up the entire line and put down new cross ties, an extensive operation which seriously delayed their advance for many days.

In a retreat every railroad building is burned, every tunnel blown in and every bridge or crossing burned or dynamited. It is not enough to blow out the piers of a bridge but the spans should be broken in the middle as well. At one point a steel bridge which the Austrians left behind in their first retreat had been wrecked by blowing out the center pier, letting the two spans drop in the middle. Along came the Russians who built up a cribbing pier of heavy timber where the stone pier had stood, laboriously jacking up the ends of the two spans as they went till they were again level and the bridge was as good as new. When they in turn retreated they burned the crib and when the correspondent who reported the incident last saw the bridge, the Germans were jacking it up again.

THE PORTABLE BRIDGE

In the advance through Serbia the German railroad builders were confronted with a serious problem. The country is mountainous. The railroads follow the rivers through the valleys and cross and recross the streams many times. Serbia is in many parts a treeless country. The forests are gone and there remain only fruit trees and scrub growth too small for construction work. The German engineers in planning this campaign decided that they needed a type of small steel bridge, easily erected and handled and adjustable so that it could be used to span openings of various widths.

The solution of this problem gave us the "Knock down," "Comepackt" bridge, one of the cleverest engineering feats brought out by the war. The idea must have been taken from the erecting toys so popular at the present time; those sets of stamped out steel sections and blocks with which a clever boy can build anything from a skyscraper to a merry-go-round. The bridge parts all come stamped out and punched and remind one much of these toy sets built on a larger scale. They have reduced their bridge members to a few standard parts which can be assembled to erect a span of from 10 to 100 feet. There are four standard pieces with the nuts, bolts, and washers to hold them together. The parts are made of pressed steel, stamped out and punched in the factory. No cutting, drilling or riveting tools are required for the erection. The work is put together cold and held in place with bolts and nuts. The only tools needed for the steel construction are wooden mauls to drive the bolts through and the plates together, and wrenches to tighten up the nuts.

The four pieces used are, a diagonal section about nine feet in length, to form the web of the trusses, a chord section for the top and bottom chords, transverse members or floorbeams to carry the load and an I-beam section on which the cross ties or plank flooring are laid; washers to insure proper spacing of the plates and bolts, and nuts to bind the whole together.

The advantages of this type of construction are many. First its adaptability. The span is built up on the spot to fit any opening. Any pieces left over from one bridge are loaded up again and used on the next. It is easy to have a great store of parts stamped out months in advance, and held at convenient points along the border to be rushed

into occupied territory. Under the old system it was necessary to find out with spies the number and size of all bridges which it would be necessary to replace, then to build these bridges in large unwieldy sections, which, when shipped into the occupied territory, often did not fit the opening they were supposed to span. On the other hand, ordinary steel bridges are sent out in assembled sections (as a plate girder) which are so heavy as to require all sorts of hoists and machinery to handle them.

Machinery is always at a premium on the front, but man power is plentiful. No piece of this new bridge is so heavy that it cannot be handled by four men, while one man can carry most of the pieces. For this reason unloading and erecting can be carried on with the greatest speed, even where no machinery is at hand. An ingenious pile driver operated wholly by man-power serves as a means of establishing foundations where the natural provisions in this line seem open to suspicion. The erecting gangs are drilled till there are no false motions in their work. They work in three shifts and find twenty-four hours sufficient time to throw a 50-foot span across a stream. The construction train comes up to the break, the engine pushing the cars of material ahead. A light false-work is thrown across the stream with material brought along or poles cut at hand. The men are soon swarming like ants on this flimsy platform and like ants we see them marching in line from train to bridge, each man carrying a bridge piece on his shoulder. The trusses grow before our eyes, and in a short time the gap is bridged with steel, the rails laid across, everything tightened up, and the false-work knocked out and loaded up. The construction train now pushes ahead over its own bridge to the next job. Empty material cars are turned over beside the track and picked up later, when there is more time.

FIELD RAILROADS

Beside the usual railroads we find the field of operations threaded in every direction by what the Germans call "Feld Railroads." These are lines of light narrow gauge track something like that used in our industrial plants. It has this difference, however; this track, built in 4-foot sections, has hooks on the ends of the rails by which the sections are fastened together. It can be laid down or taken up at any time without the use of tools. There are no spikes, bolts, nuts, or other fastening devices needed. When the hooks on the ends of the rails are engaged the act of laying the section down is sufficient in itself to lock the track sections tightly together. When the utility of the track is past it can be picked up by sections without further ado.

This field railroad has curved sections of different radii as well as switches which can be inserted where needed. In case there is only a slight change of direction the play between the sections will allow for the curvature. The cars used on this track are of a short wheel base but have a very broad floor (about 5 feet square) so that a load of seven or eight hundred pounds can be handled. The place of the locomotive with this railroad was ordinarily taken by a patient little donkey which towed the cars.

Frequently, too, they are pulled or pushed by man power. The tracks run everywhere, even up to the front line trenches where they are used at night to bring up food and carry back the wounded. This road is shelled by the enemy of course but it is a simple matter to replace the damaged sections of track as soon as night comes. A track of this kind can be laid over rather rough country, a good gang putting it down at about the rate of two miles an hour. Such expedition is invaluable in military operations—and unusual.

THE PERISCOPE RANGE-FINDER

An interesting combination of periscope and field glasses was that for range-finding from behind an obstruction,—a tree, for example. The eye-piece consisted of the ordinary binoculars; attached to these so as to make a single optical system was a long branching Y-shaped tube. The lenses were so arranged that the light falling into the objectives at the ends of the two branches was united just as it is in the ordinary binocular, and the observations for which the apparatus was designed could be made from a protected spot.

THE WAR IN THE CLOUDS

How the Italian Engineer Made it Possible to Fight the Austrians on the Summits of the Alps

BY all odds the most extraordinary thing in the way of land fighting which the World War revealed was the campaign between the Italians and the Austrians on the summits of the Alps. These summits, by the Treaties of Zurich (1859) and Prague (1866) had been deliberately left in the hands of Austria, in order that she might attack Italy with impunity when she so desired while Italy should be helpless to attack her. All military opinion, from 1859 to 1915, was to the effect that the Italo-Austrian frontier was impregnable from the south. This verdict, however, Italy disputed when she entered the war; and thanks to extraordinary engineering and still more extraordinary fighting, she showed that, at least when defended by Austrian soldiers, this impregnability was a myth.

The engineering feats in connection with the gradual reduction of summit after summit were mainly those of tunneling, cutting roads over the mountains, cutting gun-stations into the sides of peaks which might well have been supposed to be unscalable, and undermining enemy positions to blow them up. All this sort of thing is adequately described in other chapters. But there was one other striking development by the Italian engineers, which stands out all by itself as one of the crowning bits of ingenuity shown in the entire war.

THE TELEFERICA

One of the greatest difficulties which the Italians had to contend against was that of a suitable means of transport for men, guns, and material in the high Alps. Many and elaborate were the devices resorted to, prominent among which is the teleferica, or cableway. Indeed, this wonderful contrivance played an important part in enabling the Italians to hold successfully their 300 miles and more of high Alpine front during the first two years of war. And in this connection it should be borne in mind that the Austrians were never able to break through upon the Alpine front, where—until the debacle upon the upper Isonzo—the Italians, peak by peak, valley by valley, were slowly but surely pushing the enemy backward all along the line. Nor should it be forgotten that up to the very last the Alpini had their traditional foe mastered along all that 150 miles of skyline positions—from the Carnic Alps, through the Dolomites to the Trentino—which ultimately had to be abandoned only because their rear was threatened by the Austro-German advance along the Friulian plain from the Isonzo. The loss of this line under these conditions, therefore, detracts no whit from the magnificent military skill and heroism by which it was won and held.

The Italians' conduct of their Alpine campaign must remain a classic of mountain warfare—something which has never been approached in the past and may never be equaled in the future. According to approved pre-war strategy, the proper way to defend mountain lines was by implanting guns on the heights commanding the main passes and thus rendering it impossible for an enemy to traverse them. The fact that these commanding positions were in turn dominated by still higher ones, and these latter by others, until the loftiest summits of the Alps were reached, was responsible for the struggle for the "skyline" positions into which the Austro-Italian war quickly resolved itself.

This kind of war would have been a sheer impossibility two decades ago, from the simple fact that no practicable means then existed of carrying men, munitions, guns and food up to continuous lines of positions from ten thousand to thirteen thousand feet above sea-level. The one thing that made the feat possible was the development of the aerial cableway,

or the teleferica, as the Italians call it, which gave transport facilities to points where the foot of man had scarcely trod before. Regular communication with the highest mountain-top positions would have been absolutely out of the question without this ingenious device.

THE PRINCIPLE OF OPERATION OF THE TELEFERICA

In principle the teleferica is precisely similar to the contrivance by which packages are shunted around in the large stores and factories. The only point which differentiates it in the least from the overhead ore-tramways is the fact that—in its latest and highest development—it is lighter and more dependable. For the ore-tramway—always built in a more or less protected position—has only the steady grind of the day's work to withstand; but the teleferica has not only the daily wear and tear racking it to pieces, but it is also in more or less perpetual peril of destruction by flood, wind, and avalanches, to say nothing of the fire of the enemy's guns or of bombs from his airplanes. That the Italians have evolved a contrivance more or less proof against the ravages of these destructive agents is, perhaps, the best evidence of their genius for military engineering. Nothing more perfect in its way than the teleferica has been produced by any of the belligerents.

Courtesy of Scientific American.

A Long Span of the Teleferica

Which the Italians used in their mountain campaigns to transport men, guns, ammunition and other accouterments of war.

Theoretically, a teleferica can be of any length, though the longest on the Italian front was one of about four miles, which made a good part of the 8,000-foot climb up to the summit of the Pasubio, in the Trentino. The cable may run on a level—as when it spans some great gorge between two mountain peaks—or it may be strung up to any incline not

too great to make precarious the grip of the grooved overhead wheels of the basket. Although engineers have stated no limit here, no teleferica is in operation with a cable running at an angle of over 45 degrees. Wherever a cable does not form a single great span it has to be supported at varying intervals by running over steel towers to prevent its sagging too near the earth.

A teleferica has never more than its two terminal stations. If the topography of a mountain is such that a continuous cable cannot be run the whole distance that it is desired to bridge by teleferica, two—or even three or four—separate installations are built. This is well illustrated in the ascent of the Adamello, the highest position on the Austro-Italian front. One went to the lower station of the first teleferica by motor, if the road was not blocked by slides. At the upper station of this two-mile-long cableway, a tram-car pulled by a mule was taken for the journey over three or four miles of practically level narrow-gauge railway. Leaving this, a 100-yard walk brought one to another teleferica, in the basket of which one was carried to its upper station on the brow of a great cliff towering a sheer 3,000 feet above the valley below. Three hundred yards farther up another teleferica began, which landed one by the side of the frozen lakes at Rifugio Garibaldi. Three more telefericas—with breaks between each—and a dog-sled journey figured in the remainder of the climb to the glacier and summit of the Adamello.

The engine of a teleferica—its power varies according to the weight and capacity of its basket and the height and length of the lift—is always installed at the upper station. The usual provision is for two baskets, one coming up while the other goes down. As with the ore-tramways, however, an installation can be made—if sufficient power is available—to carry two baskets or three, or even a greater number.

HOW THE TELEFERICA MEETS DIFFICULTIES

The two greatest enemies of the teleferica are the avalanche and the wind—the latter because it may blow the baskets off the cable and the former because it may carry the whole thing away. As the tracks of snow-slides—the points at which they are most likely to occur—are fairly well-defined, it is usually possible to make a wide span across the danger-zone with the cable and thus minimize the chance of disaster on this score. It is only when the dread "Valanca"—as occasionally happens—is launched at some unexpected point that damage may be done to an aerial tramway.

Though the number of disasters of this kind from avalanches may be counted upon one's fingers, trouble from high wind is always an imminent possibility. In the early days of the teleferica accidents traceable to the blowing off of the baskets were fairly common; in fact, it was feared for a time that the difficulty from this source might be so great as materially to limit the usefulness of the cableway system. The use of more deeply-grooved wheels, however, did away with this trouble almost entirely, so that finally the only menace from the wind was when it came from "abeam" and blew hard enough to swing the baskets into collision when passing each other in mid-air.

All sorts of freight, from ducks and donkeys to shell and cannon, have been carried by the teleferica, and one of the best stories told on the Italian front had to do with a pig—the mascot of a Dolomite glacier—which found its way up there by means of the cable. He was a sucking-pig, and was sent up alive to be reared for the major's Christmas dinner, when the teleferica basket in which he was traveling got stuck in a drift which had encroached upon one of the steel towers. Twelve hours elapsed before it was shoveled free, and the sucking pig, when it finally reached the top, was frozen hard and stiff as one of his cold-storage brothers. It was only after he had lain in the hot kitchen for several hours that an indignant grunt revealed the astonishing fact that his armor of fat had kept smouldering a spark of life. They reared him on a bottle, and he grew to be a porker of 200 pounds or more, drawing a regular ration of his own.

On another occasion a teleferica was destroyed by an avalanche, leaving a band of Alpini marooned on the side of a glacier with only a few days' supply of food and ammunition. The difficulty was to reach these men. To have repaired the teleferica would have been the work of several weeks, and the only path leading to their eerie was scoured away by the slide. No doubt the mountaineering

genius of the Alpini would have been equal to the problem of finding their way back to safety by letting each other down by ropes, but this would have involved the abandonment of a position which it was vitally important to hold, whatever the cost.

The somewhat daring expedient of shooting a cable up from a gun was accordingly resorted to as a quick means of succoring the marooned men. A shell attached to a light cable went wide, and all attempts with high-velocity guns were failures. It was not until one of the new long-range trench-mortars was brought up that the experiment took an encouraging turn, though success was not won until the cable's line was displaced by a light manila rope. This was fired to its goal—an eminence half a mile distant and 1,000 feet high—at the first shot, and afterwards served to drag up a light cable which in turn dragged up the heavy one. In this way communication was quickly restored.

A SPECTACULAR EXPLOIT

Perhaps the most spectacular exploit ever carried out from a teleferica was that by which a troublesome nest of Austrian machine-gunners was cleared off one of the pinnacles of a great *massif* in the fall of 1916. At that time the lofty ridge was divided between the Italians and Austrians. The latter had access to one splintered pinnacle which, although there was no room to establish a permanent position there, offered a splendid vantage from which to observe all Italian movements in the valley beneath. The situation was irritating enough for the Italians even when the activities of the enemy were confined only to observation, but when he took to bringing a machine-gun up and peppering—almost from its rear—the headquarters of an Alpini battalion which held an important pass 3,000 feet below, it became well nigh intolerable.

Then one of the engineers discovered that there was a point between the third and fourth towers of a nearby teleferica from which the Austrian machine-gun position could be enfiladed with deadly effect. Accordingly the platform of a machine-gun was hung on to the cable at an angle which would make it easy to elevate and range on the Austrian position above. The exposed side of the platform was protected by a sheet of bulletproof steel. When all was ready a gunner and an engineer took up their positions on the platform and over all a black tarpaulin was thrown in order to deceive the Austrians as to the nature of the load. When the desired elevation was gained, the tarpaulin was thrown back and a rain of lead was poured upon the troublesome gun. It was so unexpected, coming from the air, that before the Austrians could turn their gun upon the aerial attackers, they were all killed, and the Italians experienced no further trouble from this quarter.

FIGHTING WITH AXE AND SAW

The Important Part that Lumber Played in the War Both On and Behind the Lines

WAR'S demand for lumber, both on and behind the lines, was something almost inconceivable. There were hundreds of miles of trenches which were not only floored with timber but walled with it on both sides. The mining operations which were continually going forward required very heavy and strong timber to shore up the tunnels as they were pushed forward by sappers. Thousands of dugouts leading off from the trenches were both walled and roofed with timber which had come from behind the lines, and a good way behind at that, because modern military operations, when passing over a forest, leave little for the lumbermen but charred and black stumps.

The need for boards was hardly more than the demand for heavy timbers. A large mileage of small railroads was utilized by the armies in the field and every time the front

was advanced or conceded, new miles of these narrow gauge roads had to be built. Of a temporary character, these little railroads were used for the vital purpose of carrying ammunition and supplies up and down the line, from the supply depots, and of course they required a large number of ties. Cord wood for fires was in great demand and telephone and signal poles were required almost as fast as they could be cut. This variety of work, of course, was more to be done with the axe and saw, and did not require the services of a mill at all. It did, however, require transportation on the instant and without waiting for any tramway.

THE NEEDS OF THE AMERICAN ARMY

With America's entry into the war, the situation, so far as the Allies in France were concerned, became vastly more acute. The ports of France were not built with a view to the landing of large armies, and were wholly inadequate; yet the speedy debarkation of the troops, with their munitions and supplies, had to be assured at all costs. The submarines forced the ships to come in convoys of ten or fifteen at once, requiring several times the docking space the same number of ships would have needed singly. Wharves, miles of wharves, were of immediate necessity. For this we must have piling and wharf timbers.

But, once the troops and supplies were landed, difficulties did not end. It was necessary to find shelter for them. Sacks of flour cannot be left out in the rain. Warehouses became necessary, warehouses of gigantic size and capacity. Railroads had to be laid in the warehouses, one depot alone requiring eighty-five miles. Lumber for these warehouses had to be furnished immediately.

Wherever possible, American troops were billeted in houses to save barracks. But the crowded condition of the country, owing to the refugees from Belgium and the invaded parts of France, made this inadequate. Our men were dying of pneumonia. We simply had to have barracks. Every suitable building that could be found anywhere in France was turned into a hospital, but yet there were not enough. We required large quantities of lumber for hospitals.

After the army was landed, its supplies cared for, and the men were in billets or barracks—in all of which wood plays the leading rôle—the army must be moved forward. As a matter of fact, it had to be moved forward even before the preparations for landing were completed. Everything was done under the utmost tension, and still not rapidly enough.

The transportation of men and guns, with munitions and supplies, required the construction of new railroad lines and the double-tracking of others. Ties became more important than guns, because without the railroads the guns could not be brought to the front. When the Germans broke through in March, 1918, and got within close range of Amiens, they paralyzed the main artery between the French and British armies. Another railroad had to be built, and built quickly. Fortunately, the Canadians had ties ready cut for an emergency.

In order to permit one organization to communicate quickly with another, it was necessary to construct telephone and telegraph lines. This called for thousands and thousands of poles.

Cooking the food and keeping the men warm meant tons and tons of fuelwood.

At the front, trenches and other defensive works called for large numbers of props, barbed-wire pickets, and other round material.

To bring up the artillery quickly over the shell-torn ground, it was necessary to build hasty roads with five-inch plank. The amount of lumber consumed as road planks was enormous.

HOW FRANCE MET THE NEEDS OF HER ALLIES

Every scrap of wood used for military purposes had to be produced in France. If France had not had the forests, nobody knows what would have happened. Fortunately, France did have the forests. The situation was saved, the war shortened by many long months. And she had them because she had practiced forestry for generations.

We must not imagine that she always practiced forestry. Like other countries, she began by destroying her forests. Eventually, however, she saw the disastrous effects of her recklessness, and gradually turned from destroying to restoring, and then to building up.

For example, 100 years ago the southwestern corner of France, extending from Bordeaux to the Pyrenees Mountains, was almost as treeless as the prairie, and was fringed by sand dunes which were constantly in movement, burying fields and houses and even whole villages. Napoleon called in engineers and foresters. These men succeeded in holding the dunes in place by planting with maritime pine; and then they planted up the whole interior of the region with the same tree. During the war this region was the largest source of lumber, not only for the French Army, but for the British and American Armies as well.

Forestery to a Frenchman is the accepted way of handling forests. He cannot conceive of handling woodlands in any other way. In France everybody, even those who are not foresters or lumbermen, understands what forestry means. When you say you are a forester you don't have to stop and explain as you do in America. It is just as clear as if you said you were a lawyer or a doctor. This universal understanding of the aims of forestry is the most potent factor in the upbuilding of the forest resources of any country. It is to the interest of the lumberman to have a perpetual supply of timber to cut; it is to the interest of the wood-using industries to have a permanent source of raw material; and it is to the interest of the country as a whole to be independent of outside sources of supply.

No wonder, then, that the French valued their forests, and were unwilling to have them needlessly destroyed. They did not forget the years of toil they had spent in creating them. Accordingly, all cutting operations were uniformly well carried out. The stumps were cut so low you could hardly see them; the tops were chopped into cordwood, and the slash thoroughly cleaned up. Because of the character of the wooded areas and forests in France, however, the equipment to be carried by the forest regiment is all of the most mobile character. Wood lots, wooded areas and forests in France are, comparatively speaking, small; large stretches of heavily wooded land are conspicuous by their absence. As a result no lumbering operations with any permanent headquarters, such as we are accustomed to hear about in our own heavily forested land, can be contemplated.

On this account, the forest regiments have to be outfitted with the most careful thought. Mobile steam-driven sawmills with a capacity of 20,000 board feet per 10 hours are the rule. In addition to these, there are found smaller portable mills of capacity up to 10,000 feet per ten hours. These are of such size and character as will permit them to be readily moved about by four-horse teams.

With such equipment the needs of the Allied armies for wood were met. Some idea of the aggregate of these needs may be got from the fact that one of the two American forest regiments in France had to its credit 205,000,000 feet of sawed lumber; 2,998,000 standard gauge and 941,000 narrow gauge ties; 1,746,378 pieces of round products; 39,595 pieces of piling and 319,057 cords of fuelwood. And there were British, French and Canadian forest units besides.

BONE AND SINEW FOR OUR AIRCRAFT

The battle of axe and saw was not confined to French soil. There is one story to tell of how it extended far into the American Northwest. This is the story of spruce. It is the account of an inspiring off-stage act in the drama of world war, with its setting in the mighty forests of the Pacific Northwest. There, devoid of the glamor and thrill of the battlefield, thousands of soldiers, loggers and millmen struggled to make the production of spruce timber adequate for the needs of the United States and her Allies. Their success was no less a factor in the final issue than the tactics of the battlefield; their campaign was prosecuted with foresight, skill and energy.

No chapter of the war outside the actual battle zone is more enthralling than this one. Spruce has become a magic word. Of this wood are our winged fighters built—beams, struts, braces, all the wooden parts except the propeller blades, and even for these spruce is sometimes used, alone or in combination. So production of spruce timber in desired quantities is an enterprise to which the Signal Corps addressed itself with a thoroughness bound to spell success.

That there was any shortage of spruce may be surprising. Most of us have thought of this wood as a commonplace one, realizing that spruce forests cover vast areas. But there

are many varieties, of which Sitka spruce alone is acceptable for airplane manufacture. And while white spruce, black spruce, Engelmann spruce, or some other member of the family may be found in many localities, Sitka spruce is a stranger to every part of this hemisphere except a narrow ribbon along the coastline, beginning in northern California and continuing through Oregon, Washington and the islands and mainland of British Columbia into Alaska. In this 1,300-mile strip there are few facilities for lumbering save along the coast of Oregon and Washington. It is to these states that the United States and her Allies looked for 95 per cent of their airplane stock. It was a big order; but Uncle Sam undertook the problem in a big way.

"Airplanes will win the war" was but another way of saying that spruce will win the war. Sitka spruce, the only variety here discussed, has been found the ideal. It has all the necessary qualities, particularly the prime requisites of strength and lightness. There are lighter woods, there are stronger woods; but the combination of lightness and strength is possessed by spruce alone. Other materials that have been tried, including metal rods and bamboo, have all failed in some important particular. Italy experimented with Douglas fir, doubtless as an expedient forced by the difficulty of getting the spruce; but fir is heavier. Port Orford cedar, which grows in southern Oregon and northern California, has been found acceptable, but the supply is small. Spruce is 10 per cent better, in resilience and lightness, than any other wood; and it is just this 10 per cent that gave us the victory in the air.

The production of spruce boards for airplanes is the most exacting business that our lumbermen face. Every piece must be perfect. The grain must be true and must not run out; there must be no knots, pitch pockets, or other faults. In producing any other material a certain amount of inferior stock is expected as a matter of course. But there must be no seconds in airplane lumber; the slightest blemish may spell disaster.

The spruce tree is a forest giant. With massive base up to 12 feet in diameter, the bigger trees send their pointed tops to a height of 160 or 180 feet, standing sturdy and straight for 80 feet to where the first branches reach out with their foliage of yellow green. The finest trees are selected for aircraft lumber. From the lower slopes of the Coast Range and the Olympics, where they have stood guard for five or even eight hundred years, they are felled and hauled to the mills. When possible the logs are cut into timbers upward of 40 feet long, at least six inches wide, and two inches thick. This is ideal aircraft lumber; but many pieces may be discarded for imperfections for every one that is accepted.

These large pieces are used for beams; the smaller cuts are fashioned into wing beams, braces and struts. It is comparatively easy to find clear spruce for the pursuit planes, slender falcons of the air with wing spread of 20 feet or thereabouts. It is far more difficult to cut unblemished timbers for a heavier machine like the Caproni, with a wing spread of 100 feet or more. Fortunately there are few defects in spruce that do not show on the surface—another quality that commends this wood to the birdman.

The wastage in airplane stock is very heavy. It has been found impracticable to size the parts at the mills, and when the timbers reach the factory much must be thrown away. The builders in 1918 used approximately 800 feet of lumber in preparing the 167 feet actually included in the average biplane. Wasteful as this may seem, it was a vast improvement over earlier best performances, under which 2,440 feet went for a single plane; but the engineers hoped to reduce the figure to 600 feet. Laminated construction, masterpiece of the joiner's art, resulted in considerable saving. Small pieces are more likely to be without defects than are large, and these, by scientific splicing, are built into beams as strong as one solid timber. No nails are used in joining these boards, or in putting together the frame of the airplane; for nail holes would weaken where every particle of strength must be conserved.

MINES AND COUNTERMINES

How the Modern Army Blows Up the Foe and Seeks to Keep Him from Returning the Compliment

WAY back in 1863, when Grant was beginning to wonder whether he would ever take Vicksburg by direct bombardment and assault, he set his engineers to work tunneling beneath the huge bluffs on which the city stood, with the intent of blowing them off the map. The beleaguered Confederates, aware of this underground attack, endeavored by driving countermines to intercept his bores and frustrate his efforts, or at least to attain a position where they could blow up his tunnels themselves. They were unsuccessful in this, as the Union commander was unsuccessful with his mine, which he exploded before it had penetrated far enough to be of real effect.

The World War saw a renewal of this style of conflict, in which the commanding rôle is taken by the engineer. In France, from the moment when they realized that the Germans in their trenches, contrary to all the rules of the game, were going to take a tremendous amount of beating before they would be beaten, the Allies fell back upon mines, and the Germans perforce upon countermines. In some places the German positions dominated those of the Allies to such an extent that seemingly the only form of attack which promised any notable results was attack by mining.

From the engineering standpoint, this sort of thing is interesting enough, but by no means extraordinary. It is just the same kind of game as digging a railroad tunnel or any other bore. The same apparatus is used, the same means employed to direct the tunnel to its goal —it is in every way the same problem. But at least one of the mines driven by the Allies deserves honorable mention on two grounds— the fact that it represented the biggest charge of explosive ever set off at one time, and the rather surprising nature of the precautions adopted against German countermines.

The Messines Ridge, the hill that dominates Ypres from the south, was in the possession of the Germans. The success of the Allied military operations in that part of the front depended upon dislodging the enemy from this exceptionally strong position. All efforts to take the hill by storm failed, with great loss of life. Only one plan of operations seemed feasible—to mine the entire ridge and literally blast it off the face of the earth.

THE GEOLOGIST IN THE WAR

The actual mining offered no particular engineering difficulties, but mining is an operation that takes time, and anything that required an appreciable time for its completion in this war was reasonably certain to be discovered by the enemy before it was finished, so difficult was it to hide any sort of activity from the prying eyes of the scouting airplane. There seemed to be no way to undertake the gigantic scheme of mines that would be necessary without inevitable discovery that would give the Germans the cue to sink countermines and render the whole operation futile. At this juncture the geologists were called in.

All of the region through which the battle-lines pass has been studied by geologists for a century or more. There is not a square inch of the surface that has not been minutely mapped, while the underlying formations and strata are as familiar to geological students as though they had been exposed in cross-section. Both the French and the Belgians have published many excellent geological maps of the entire terrain. Armed with these maps and the available data, the scientists made their report to the British General.

"If you mine in this direction, and at this depth," they said, indicating certain positions on the map, "you can work without fear of countermines, for at these points which we have marked there are beds of quicksand, whose depths and areas we have here indicated,

so located as to render countermining by the Germans impossible."

The counsels of the geologists were heeded. Mining operations had been under way but the briefest time when the Germans discovered what was going on. Countermines were begun, but the Germans, less well supplied either with data or with geologists, encountered quicksands that made further progress impossible. The British saps were driven into the very heart of the ridge. More than fifty high-explosive mines were planted, containing in the aggregate 500 tons of high explosives, and on June 7th, with a detonation that shook the earth for miles around, the mines were exploded.

What had been the crest of the Messines Ridge became a crater. Concrete emplacements and deep dugouts were as a house of cards against the terrific forces which hurled them into the air, in more or less atomized form. Strange as it may seem, some German troops came through this frightful ordeal, but so dazed were they by the force of the explosions that their subsequent resistance was quite ineffectual against the onrush of British troops which stormed the entire ridge, and advanced some distance beyond. Hundreds of Germans were killed and some 7,500 prisoners and 47 guns taken by the British who held the captured position.

While this was the most spectacular feat of the geologists, some of them of world-wide reputation, whose services to the Allies were very real and constant, their exact knowledge of subterranean conditions was continually turned to a variety of uses. With every change in the positions of the opposing forces on any sector of the front, new maps were prepared, on which data of use to a commanding officer was indicated by means of vari-colored inks and symbols. One color, for example, indicated "Here it is safe to build dugouts," while another indicated "No chance for dugouts here—rock five feet below the surface." Trench locations, favorable and unfavorable, were indicated, with quicksands, chalk-beds, caves and other subterranean phenomena. As the water supply of the forces in the field is of the greatest importance, every point at which the geological indications point to the obtaining of water by digging was carefully indicated on these maps, which also showed where it was safe to dig mines and tunnels.

Since there is a considerable body of underground flowing water throughout Northern France, vertical cross-sections of the terrain at various points were drawn, in order that these underground water systems might be studied and the probable rise and fall of subterranean rivers and lakes be anticipated before such movements interfered with tunneling operations or made dugouts and shelters uninhabitable.

One observer stated that "every man of note in the scientific life of England is at work for his country and there is no branch of science that is not being applied in this war." The utilization of geology on any such scale, at least, is certainly unique in the history of warfare. Germany in the beginning of the war called its scientists to the aid of the Army. Later, conditions were reversed, and men of science played by far a greater part in the councils of the Allies than in Germany's.

MINING THE ALPS

On the Italian front, too, mining operations figured conspicuously in the advance of the Allied troops; in fact, the very nature of the fighting along the Alpine front lent itself admirably to sapping operations. In contradistinction to the mining operations on the Western front, the Italian mining operations were carried on mostly through solid rock, so that the work represented the last word in tunnel engineering.

In 1916 the Italian forces decided upon the mining of a peak known as the Castelletto, which was over 12,000 feet above the level of the sea, in the Dolomite region. The Austrians, it appears, had not only made the most of the splendid natural defenses of the peak, but had carved out caves and loopholes in the rocky mass, converting the Castelletto into a veritable Gibraltar. Because of the mass of machine guns and light quick-firing pieces concentrated in the caves of the peak, the Italians soon learned the futility of attempting to take the position by usual means; mining, it appeared quite certain, was the only method which offered any hope of success.

In all, the Italian sappers pierced a tunnel

1,663 feet in length through the rocky mass of the Dolomite mountain, requiring the excavation of over 2,200 cubic yards of rock. Pneumatic drills were employed for the bore holes, and at first the blasting was carried out with military gelatin and later with dynamite. For the work four squads of sappers were employed; each squad, comprising a foreman and 25 to 30 men, worked six hours at a stretch.

It was originally intended to divide the explosive charge between two chambers, each having a mining line of resistance of about sixty-six feet with a 16-ton explosive charge of 92 per cent gelatin. However, owing to the countermining work carried on by the enemy—the Italians were only a few yards from one of his positions during the charging of the mine chambers—it was necessary to confine the entire charge to a single chamber in order to insure reasonably that operations should not be interrupted by a hostile blast or by actual breaking through of the enemy galleries into those of the Italians.

The enemy, meanwhile, with a view to avoiding the effects of the mine beneath the peaks of the Castelletto, had transferred most of his shelters to the side of the Tofana and the Selletta. This necessitated a considerable alteration in the location of the mine as originally planned, in order that it should act against the enemy shelters on both the Castelletto and Tofana flanks rather than on evacuated soil.

The charge was computed on a basis of minimum resistance of about sixty-six feet, taking into consideration the nature of the rock (which was fissured) and the existence of numerous splits and caverns. The coefficient of overcharge was, therefore, rather high. In order to obtain the maximum effect under these conditions, only 92 per cent explosive nitro-glycerin was used. The total charge was 35 tons.

The tamping was effected with cement and with sandbags, with heavy wooden beams between the latter. It was made more effective by dividing into sections at right angles to each other. The theoretical length of the tamping was about eighty feet.

The mine was sprung on the 11th of July, at 3:30 p. m., and responded fully to the fondest expectations of the Italians.

A STETHOSCOPE FOR THE EARTH, TO DETECT MINING OPERATIONS

If the enemy is going to mine, we have got to countermine; and this of course means that we must learn, with a minimum of delay, when and where he is mining. We cannot depend upon chance to get wind of his intentions; we must have a better means than that for learning what he is about. He is bound to make some noise in his mining; and the microphone we have always with us when it comes to devising apparatus for the detection of faint sounds. But the French engineers who attacked this problem began from another angle, for the very good reason that not all vibration translates itself as sound. Moreover, microphone tests show that there is a limit of faintness well within the danger zone beyond which the sounds of pick and shovel and drill are not detected by the electrical apparatus. So we have the geophone, which is really a stethoscope for the earth, and which it appears will be of vast advantage in peace as well as in war.

The geophone has nothing electrical about it; it is mechanical entirely and operates upon the principle of the seismograph, the instrument used for detecting and recording earthquakes. As the reader undoubtedly knows, the seismographic principle is that of a so-called steady mass which remains practically motionless because of its inertia, when the earth moves beneath it in seismic disturbances. Having thus a point in motion (the earth), and a point stationary (the steady mass), the seismologist is able by means of a chronograph drum and pen to record the amplitude and duration of earth vibrations.

The geophone consists of an iron ring about three and a half inches in diameter, within the center of which is suspended a lead disk, fastened by a single bolt through two mica disks, one of which covers the top and the other the bottom of the ring. Two brass cap pieces are fastened with bolts to the iron ring to hold the mica disks in place, the top one having an opening in its center to which is fastened a rubber tube, leading to a stethoscopic ear piece.

The apparatus, then, consists of a lead weight suspended between two mica disks cutting across a small air-tight box. If the instru-

ment is placed on the ground and there is any pounding or digging in the vicinity, energy is transmitted as wave motion through the earth, and earth-waves shake the geophone case. The lead weight, on account of its mass and because it is suspended between the mica disks, remains comparatively motionless. There is then a relative motion between the instrument case and the lead weight and a compression and rarefaction of the air in the instrument takes place. Since the rubber tube leading to the stethoscopic ear piece is connected with this space in the geophone, this rarefaction and compression is carried to the ear when it makes itself manifest as sound. The principle is that of the seismograph in every detail save that the shock is translated into a sound for convenience of observation.

It should be noted that it is not necessary for sound, meaning vibrations of such range as comes within the compass of the human ear, to reach the geophone in order that sound may be heard in the ear pieces. The wave motion communicated through the earth may be as absolutely soundless as is the electric current which serves to transmit a telephone conversation, and yet be transformed to sound in the air-chamber of the geophone, much as the electrical energy in the telephone circuit is made manifest in the receiver as sound, though no actual sound passes over the wires.

THE GEOPHONE IN PEACE

The geophone, which was developed by French army engineers and is now in use by the United States Bureau of Mines in connection with mine rescue work, has a number of peculiarities which particularly fit it for the work it has to do. One of these is the readiness with which the ear recognizes which of two sounds in two geophones reaches the auditory nerves first. The same phenomenon is taken avail of in Dr. Callahan's apparatus for detecting fraudulent claims of deafness, described in another chapter. Two geophones are used, one for each ear. The impression is that the sound in one ear is louder than the other; that it is not actual loudness, however, is proved by the readiness with which an operator slightly deaf in one ear is able to orient sounds. In using two geophones, it is merely necessary to move them about against the wall through which the vibrations are coming, until a point is found where the sounds have the same intensity to both ears. The direction in which the sound comes, then, will be perpendicular to a line connecting the two instruments. Whether the sound be in front of or behind the observer is a matter for further observation, but is readily determined.

What such an instrument may mean in mine rescue work can be best appreciated by those who have attempted to locate entombed miners by other means. Knowing where to dig and in what direction is often three-fourths of the rescue campaign.

The instrument is extremely sensitive, not only to vibration, but to variations in the vibrations, so that it is very easy to detect the source of the sound, whether it is pick, hammer, explosion, fire, running water or whatever the cause of the earth-waves may be. An experiment was made by a Bureau of Mines engineer who had never used the instrument before; after listening to sounds caused by twelve different mining and carpentering operations he was able, with ease, correctly to name nine of them and accurately to describe the other three sounds although they were too unfamiliar to him to allow him to name them.

While not unlimited the geophone is not narrow in its range; a pick striking into bituminous coal is easily heard through 900 feet of intervening coal and earth, and a sledge pounding can be heard 1150 feet with sufficient clearness to enable the direction to be accurately noted. The explosion of an ounce of dynamite transmitted wave energy, translated as sound in the geophone, for more than two thousand feet.

Another surprising feature of the geophone is that the presence of intervening rooms, galleries and entries seems to have little effect on the resulting sound. Apparently the earth-waves are transmitted in all directions and are picked up by the geophone without much regard to the continuity of material between it and the source of the vibration. This is a very important factor in considering the instrument as an aid in mine rescue work.

Another phenomenon of the geophone is the readiness with which it picks up sounds through the mine cover, although this readiness is largely influenced by the state of the

air outside, any great amount of breeze seriously interfering with its action. A man pounding with a sledge can be located two or three hundred feet under the surface, from the surface, and at the experimental mine in Bruceton, Pa., a miner has repeatedly been located within 50 feet, through 150 feet of cover.

THE GEOPHONE IN METAL MINING

The geophone is by no means limited to rescue work in mining operations. In metal mining, experiments are proving that it can frequently take the place of difficult and expensive surveys designed to bring two borings to a meeting. This is not theory, but the result of an actual experience, in which Bureau of Mines engineers located the trouble in a metal mine where a drift and raise, supposed to meet, had missed. Observations were made in the drift, of pounding, in the raise, and then observations were made in the raise, of poundings in the drift. The engineers concluded that the two had missed by about six feet, and named the direction of each from the other. Not willing to trust the new instrument, the mine operators insisted on a survey, but when it was made the result was as already determined by the geophone. The instrument is particularly useful in direction determination in the metal mine, rather than a coal mine, because metal bearing rock transmits the vibrations in a more clear-cut manner than coal. This is probably because there is some reverberation to the sound from a blow on wood, while on the stone the sound is clean-cut. Observations were made in another raise which was being driven up, about six or eight feet distant from a drift. Observations were made in the drift, of the sound from the drill in the raise, and a point located on the side of the drift behind which the drill in the raise was apparently operating. The survey mark was two and one-half feet to the right of this mark. A drill set up and operated at the survey mark did *not* break through into the raise, but a hole drilled at the point in the drift located by the geophones reached the raise and proved the geophone observation to have been correct within a few inches.

Mining engineers believe the geophone will be useful in preventing accidents from explosions, when breaking through. This yet remains to be tested, but it is certain that within several hundred feet, it is perfectly possible to distinguish the difference between tamping a charge, using a pick, hitting with a mallet or a sledge or almost any other sound. It is difficult to describe this ability of the little earth stethoscope to make sounds recognizable, but it is remarked by all who use the instrument for the first time.

Observations were made recently of a mine fire burning from twenty to forty feet below the surface. A low rumbling noise could be heard as if air were being drawn in long crevices, and occasionally sounds could be heard from the snapping and falling of pieces of coal or rock. As well as can be determined, the fire area was accurately located, but owing to the fact that the fire could not be approached from the inside the data was not checked absolutely. It is interesting to note that similar sounds were heard from only one point on the inside of the mine and that that point was the one nearest the area as located on the surface.

It has been found also by the Bureau of Mines engineers that the instruments can be employed quite advantageously in locating knocks in automobile valves and cylinders. For this purpose it is well to mount the instrument on a short iron rod that can be easily inserted in and around the machinery. In this manner not only can a troublesome cylinder be located, but the trouble area in the cylinder can also be found.

GUN FIRE AND THE NOISES IT PRODUCES

The velocity of sound is about 1150 feet per second. Every self-respecting big gun sends its projectile away at a rate in excess of this, leading to a curious phenomenon. The shell arrives at its destination first, and is followed after an interval by the report of the gun that fired it! And even more remarkable, the "pressure waves" which the shell throws up in the air, much like the bow-waves that are to be seen streaming off sideways from any steamboat, are audible! This complicates sound-ranging, for the sound of the cannon's shooting has to be carefully picked out from the shriek of flying shells.

WIRELESS AND THE WAR

Some of the Remarkable Achievements of Radio Engineers in Maintaining Wireless Connection Between Ships, Airplanes and Land Stations

THE recent remarkable development of wireless telegraphy and telephony is a story of coöperative invention. Prior to America's entrance into the World War, the various wireless interests were engaged in the usual business competition and only too often blocking each other's way and the general progress of the radio art by patent litigation. One might have a remarkable development on an existening instrument; but someone else had a basic patent on a feature of that instrument. So the man with the improvement was blocked by the basic patent; and the holder of the basic patent, in turn, was powerless to improve his instrument because of the blockading patent on the improvement.

A LESSON IN COÖPERATIVE INVENTION

Then came the war. The various wireless organizations were called upon to give our fighters the very best to be had in radio instruments. Patriotism and devotion set aside all commercial and professional rivalry, and patents were momentarily overruled where the interests of our government were concerned. And what counts for more than any other single thing, the inventors and engineers of the various radio organizations and the leading electrical and telephone companies got together and pooled their ideas and experience for the common good.

As might well be expected, much came out of this coöperative work. Indeed, the wireless telephone, which but a year or two ago was a delicate, uncertain child of the laboratory, suddenly developed into a full-sized, robust, practical means of communication available for ground use and aircraft. Baffling problems in interference prevention have been more or less solved. Long-distance stations have suddenly become operative under almost all atmospheric conditions. The business capacity of huge stations has been increased many fold. The lofty aerials formerly required for long-distance reception have been abandoned for underground aerials and small loops from three to six feet in diameter, erected four or five feet above the ground, while it has been discovered, too late for use in the field, that every tree is as good a receiver as a wireless man could ask. And so it goes with many other features of wireless, which only yesterday were considered the far-off goal of wireless men and which to-day stand practically perfected as a result of unselfish, coöperative effort.

WAYS NEW AND OLD OF GENERATING RADIO WAVES

Turning first to transmitters, we find spark transmitters still employed to a large extent, although many new forms of transmitters have made their appearance. One of these is the arc generator, which, if not absolutely new, is at least greatly improved in its present form. It is widely employed both in Europe and America. Starting with the simple arc of the Danish inventor, Poulsen, back in 1906, radio engineers have brought this generator to a high state of perfection for long-distance telegraph and telephone transmission. In fact, the recent development of the vacuum tube as a modulator of circuits has made it possible to impress telephone conversations on the most powerful arc transmitter, thereby making the latter more than ever available for practical wireless telephony.

For years wireless engineers have appreciated the convenience and practicality of the high-frequency alternator as a means of transmitting. However, there is a vast difference electrically and mechanically between the gen-

erating of currents of 60 or 133 cycles, as in commercial power circuits, and the 20,000 cycles required for radio transmission. Still, these electrical and mechanical obstacles have been slowly overcome, both here and abroad. Among others, there has been the Goldschmidt alternator, which makes use of a most ingenious winding scheme for multiplying the frequency within the machine until radio frequencies are obtained.

The Goldschmidt alternator has been in use for some time past, particularly at Tuckerton, N. J., and Eilvese, Germany, giving excellent results. Driven by a 220-volt, 250-horse-power motor at 4,000 revolutions per minute, the Goldschmidt alternator supplies radio-frequency currents. The accuracy of construction of such an alternator is extreme; indeed, the air gap clearance between rotor and stator is but 0.03 inch, and a deviation from parallelism of one part in a thousand causes the output of the machine to be reduced by one-fifth.

As far back as 1908, Dr. Ernest F. W. Alexanderson of Schenectady, N. Y., constructed an alternator delivering approximately two kilowatts of 100,000-cycle current. The rotor of this alternator made a speed of 20,000 revolutions per minute, the actual speed at the rim being 12 miles a minute. Other inventors have also worked on high frequency alternators, and all this work has finally given birth to the present successful generators. The advantages of this type of generator are numerous. For one thing, it gives a steady, uniform supply of radio energy, which only needs to be controlled by telegraph key or microphone amplifying circuit, according to whether telegraphy or telephony is sought.

TELEPHONING THROUGH 3,200 MILES OF SPACE

In 1919 Dr. Alexanderson's apparatus was employed by the Navy Department at New Brunswick for transmitting wireless telephone messages to President Wilson on board the transport *George Washington* at Brest, France, or over an air-line distance of 3,200 miles. And, according to this leading radio engineer, this is by no means the limit for wireless telephony, especially when better facilities are available.

The station at New Brunswick, employing Dr. Alexanderson's high-frequency alternator, may be used either for wireless telephone or telegraph messages without alterations, and for simultaneous transmission and reception of either. The alternator at this station has a frequency of 22,000 cycles, and the only moving part is a solid steel wheel without wires or copper conductors, constituting the rotor. This member revolves at 2,100 revolutions per minute. The output is 200 kilowatts, and the emitted wireless waves have a clear-cut whistle or flute-like sound, with no harmonics. It should be remembered, however, that these waves are inaudible because of their high frequency, and special means are employed at the receiving end to convert them into audible or readable signals. Harmonics, Dr. Alexanderson explains, have various frequencies and different wave lengths, and interfere with other stations. They are useless wave lengths which fringe signals.

In conjunction with his alternator, Dr. Alexanderson makes use of a magnetic amplifier, which builds up weak currents until they become sufficiently powerful for long-distance transmission. This device contains no moving parts; magnetically, it controls the output of the alternator at the bidding of a telegraph key or microphone. As far as the layman is concerned, the magnetic amplifier may be described as a special form of transformer.

Still another feature of the Alexanderson system is the multiple-tuned aerial, which is said to purify as well as amplify the particular tone or vibratory frequency of the station's generator. Dr. Alexanderson makes his aerial in electrical harmony with his transmitter, whereas the general practice has been to use any kind of aerial for handling the transmitter's oscillations. A suitable analogy is the phonograph: the cheaper machines are merely assembled, with any reproducer, tone arm, horn, and cabinet being brought together to form a machine. The more expensive machines, which really reproduce something like the living sounds, are not merely assembled—they are carefully balanced. Each part is balanced against some other part, so that the acoustic ensemble is a perfect unit. So with the Alexanderson transmitter and aerial; they must agree so that there will be no opposi-

© Gilliams Service.

Talking from Airplane to Ground

The aviator wears a wireless transmitter that is deaf to everything but the aviator's voice.

tion or depreciation. As a result of this balance, the range is greatly increased. Thirteen poles, each 400 feet high, are employed for the aerial at the New Brunswick station.

The Alexanderson system is also employed in the powerful wireless station at Lyons, France, which has been handling the official United States Government traffic between the two countries. The aerial of this station comprises 20 parallel strands of phosphor bronze cable extending over a distance of 2,400 feet and supported on eight steel masts measuring 650 feet in height. The station makes use of several transmitting sets, namely, a 150-kilowatt Alexanderson high-frequency alternator, a French high-frequency alternator of the Bethenod design and of the same capacity, two 250-kilowatt Elwell arc generators, and two 150-kilowatt spark sets. As we write in July, 1919, the two high-frequency alternators have not as yet been put into operation.

The United States Naval Radio School at Harvard University

VACUUM TUBES—THE MODERN ALADDIN'S LAMP

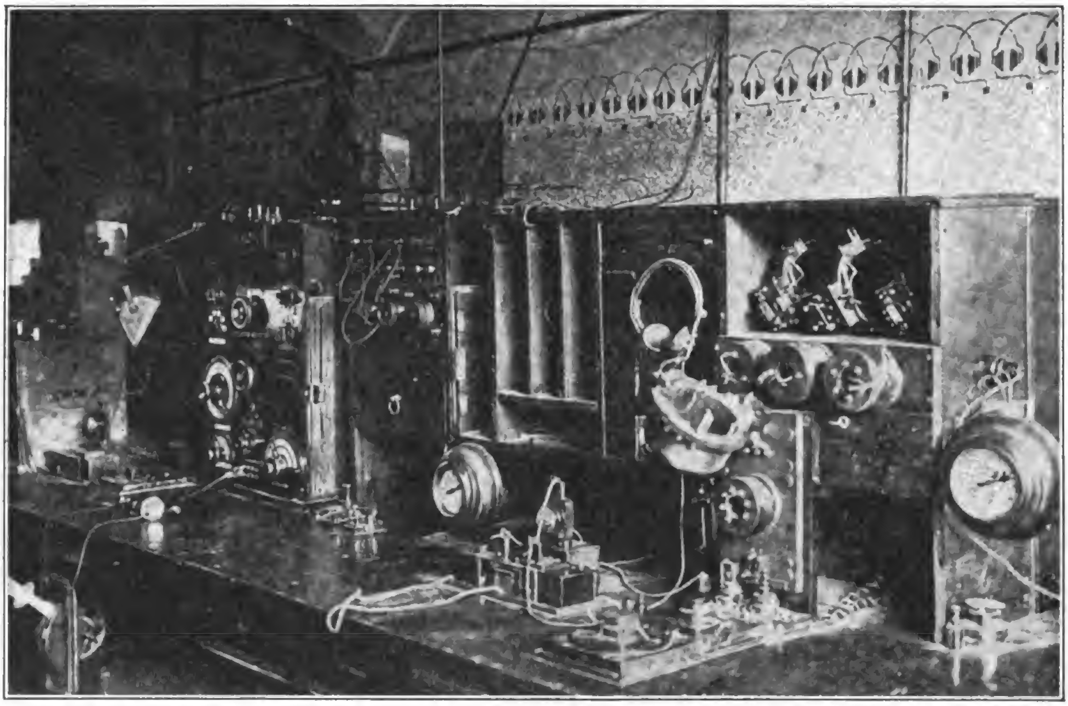
And now we come to the most remarkable development in radio communication—the vacuum tube. Many years ago Edison discovered that when an electrode was inserted in an ordinary electric bulb and the filament heated to incandescence, current flowed from the filament to the electrode. In other words, the lamp became a uni-directional conductor, and was thus available for rectifying purposes. This phenomenon has since become known as the "Edison effect."

After Edison, numerous prominent inventors took up the Edison effect and studied it with a view to making some use of this simple rectifier. Among them have been Fleming, DeForest, Langmuir, White, Armstrong, Craft, Colpitts, and others. The story of the gradual development of the vacuum tube, as it is commonly called, is a long one, but suffice it to say here that up till 1912 no remarkable progress had been made.

Then it was that the telephone interests, with a view to improving their long-distance service by introducing means of repeating or amplifying weak currents, decided to investigate the vacuum tube. From a comparatively crude instrument the telephone engineers, with every facility available for extensive research

and experiment, soon evolved highly perfected vacuum tubes which became competitors of the so-called "mechanical" repeater, which they are rapidly displacing. Ordinary telephonic communication is not feasible over 500 miles, without some means of repeating or relaying the attenuated current coming from the transmitter. Thus for distances between 500 and 1,200 miles, two amplifiers or repeaters are employed. In speaking through to San Francisco from New York City, a person's voice travels through six vacuum tubes.

And while the vacuum tube, in its perfected form, practically perfected long-distance telephony and multiplex telephony, it all the while became better adapted to radio communication. Appreciating its vast possibilities, the telephone organization back in 1914 began wireless telephone experiments between an experimental station at Montauk, L. I., and Wilmington, Del. In April, 1915, good wireless telephone transmission was achieved between the two stations. This experimental and development work was steadily expanded by the telephone organization's engineering staff and numerous radio engineers, until, on October 23, 1915, telephone messages were transmitted through space from Arlington, Va., to the Eiffel Tower in Paris, France, a distance of 3,600 miles, and to Honolulu, Hawaii, about 7,000 miles! A large battery of vacuum tubes, arranged as generators, and others arranged as modulators, were employed in these long-distance tests.



Courtesy of Scientific American.

The German Wireless Station at Metz

Like many another fable, the Germans were supposed to be leaders in radio communication before the war. Yet as the war progressed, the Allies soon learned that their own wireless equipment was superior to that of the Germans. When America entered the struggle the Allied supremacy became absolute.

The vacuum tube, in its present form, is made in various designs, although fundamentally it consists of one or more filaments which can be heated to any degree, and two or more electrodes. The theory of what takes place within the bulb is complicated, hence must be avoided here for lack of space. However, the present vacuum tube is available as a de-

tector of wireless signals and wireless telephone waves, as a modulator or relay, as an amplifier or builder of weak currents to powerful currents, and as a generator of alternating currents of a wide range of frequencies. It is indeed an electric acrobat.

ELECTRIC LAMPS WHICH HAVE MADE WIRELESS TELEPHONY PRACTICAL

Given a perfect amplifier and a perfect modulator, the problem of radio telephony is solved, at least theoretically, for all that is necesssary is to modulate the output of an oscillating circuit and then, if necessary, amplify the modulated current to any degree in order to obtain a sufficient volume of current in the aerial for transmission through space. Or one may first generate oscillations of large power and modulate them by means of the amplified output of the telephone transmitter. That is why, with the perfected vacuum tube, wireless telephony was practically perfected overnight. It became possible to telephone from airplanes to the ground and vice versa; to telephone over land lines to a wireless station, which in turn sent out the conversation to a battleship or steamer, and to receive the answers back through the wireless station and land lines; and to telephone through space many thousands of miles. Of course, many details had to be solved. The noises of the airplane had to be contended with, by the development of special ear-pieces and helmets, as well as by special transmitters which would respond to the voice and not to the extraneous sounds. And with our Army and Navy in need of thousands of bulbs a week, the design and manufacturing methods had to be altered so as to permit of quantity production.

Like nothing else the vacuum bulb proved the greatest single contributor to wireless communication. Quite appropriately, it has been referred to as the modern Aladdin's lamp.

Thanks to the sensitiveness of the vacuum tube as a wireless wave detector, and then to its amplifying properties which make it possible to build the weakest currents up to any volume without distortion, aerials for receiving purposes have begun to shrink to small proportions. Thus it has become possible to make use of exceptionally small aerials and even buried aerials. Indeed, James H. Rogers of Hyattsville, Md., has developed an interesting form of underground wireless which has been used by our Navy with excellent results. This system makes it possible for submarines to receive wireless messages over great ranges without coming up to the surface. Incidentally, this system, it is understood, practically eliminates static—which is the free electricity due to atmospheric conditions—as well as interference from undesirable stations.

RECEIVING THOUSANDS OF MILES WITH A THREE-FOOT WIRE LOOP

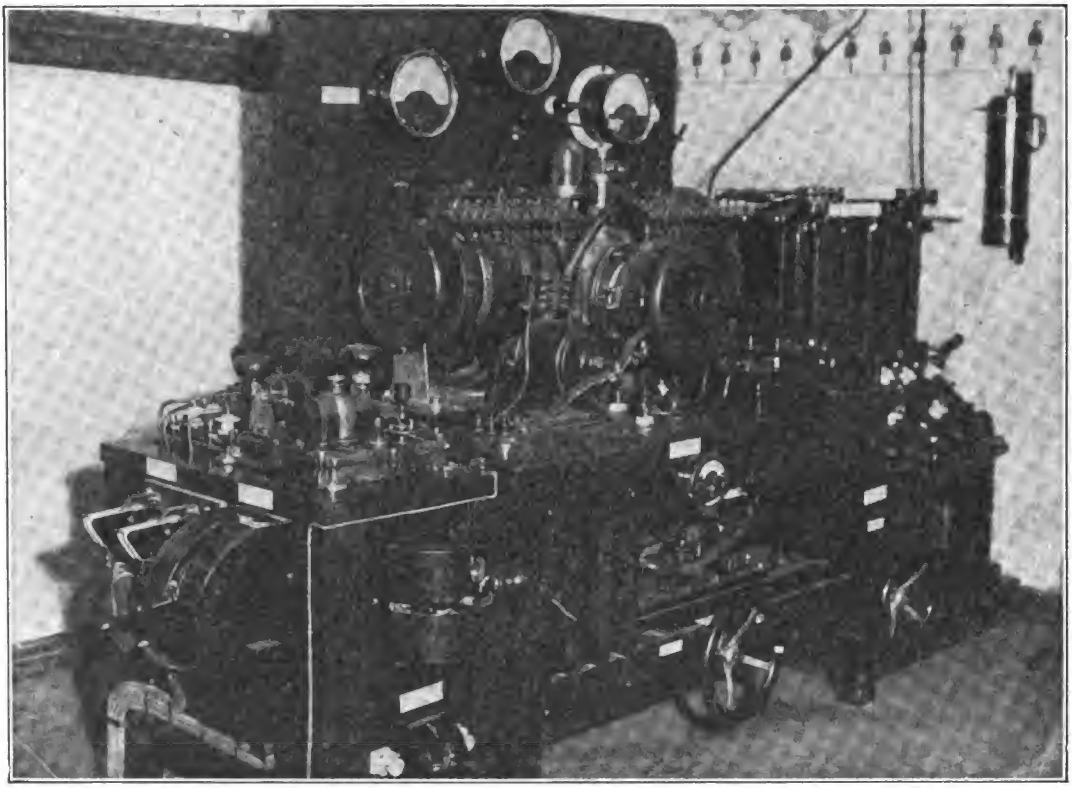
Another recent development in wireless reception is the use of a simple loop aerial, say three to six feet in diameter, with which it is possible to receive waves from stations thousands of miles away, provided proper apparatus is employed. In fact, it is as certain as well can be that ultimately a loop aerial will permit an amateur to receive signals from almost all over the world. And the loop, most remarkable of all, can be used indoors. However, for transmitting long distances the elevated aerials are not going to disappear so soon, because it is mostly the reception of messages which lends itself to buried aerials and loops. What makes the loop so efficient is its positioning in the proper plane, so as to intercept the waves to the best advantage. The loop is employed on certain Army and Navy planes for the purpose of receiving direction signals. Thus it becomes possible for the pilot, by maneuvering about until he receives the loudest signals from a ground station, to locate the direction of the station. The loop, in that case, is generally incorporated in one of the planes.

How the United States Government kept in touch with our forces and diplomats overseas is one of the most interesting stories of modern radio communication. Indeed, early in the war information was received that the Germans were making extensive preparations for the cutting of the cables for the purpose of interrupting our communication with Europe; and this fact, more than any other, gave a tremendous impetus to wireless. As it was, three cables were actually interrupted, and excellent evidence is at hand that enemy influences were responsible. Wireless telegraphy was called upon to assume only part of the

burden of cable traffic, which often aggregated 200,000 words in each direction per day, and at no time was the radio service worked to full capacity.

It is from a little room in the New Navy Building at Washington, D. C., that all our trans-Atlantic radio traffic is handled. The Navy operates four powerful stations—Annapolis, Md., New Brunswick, N. J., Sayville, L. I., and Tuckerton, N. J. The Annapolis station, with its four 600-foot towers, is believed to be the most powerful station in the world. It has a 350-kilowatt transmitter. The New Brunswick, Tuckerton, and Sayville stations are rated at 200 kilowatts each. All these stations are operated from Washington, by means of land lines. Whereas other governments operate their wireless stations at the very base of the lofty towers, we have gone a step ahead of them by centralizing our stations in our Capital.

There are four tables in the trans-Atlantic room, each table connecting with one of the four stations. On each table there are two ordinary telegraph keys, one of which is directly connected by heavy land cable with the transmitter at its respective station. The operator, sitting at Washington, operates the transmitter at the wireless station, without delay and without the services of another operator. The other key serves to telegraph any instructions as to the manipulation of the transmitting equipment.



Courtesy of Scientific American.

The Machine Through Which an Arc Light Talks Across Thousands of Miles

One of the most efficient methods of long-distance radio transmission employed to-day is the electric arc, which is similar to the carbon arc employed for illuminating purposes. Here is shown an arc transmitter used by the Germans at the Metz wireless station.

OPERATING A WIRELESS STATION FROM A DISTANT POINT

Each operator wears a pair of telephone receivers which enables him to hear the sig-

nals from the transmitting station which he is operating. The receiving aerial is erected on the roof of the Navy Building at Washington, carefully attuned to the wireless stations to which it belongs. One table operates the New Brunswick station, which may be working with the steamer *George Washington.* The second operates the Annapolis station, which may be working with Lyons, in France. Ordinarily, the New Brunswick station also operates with Lyons, insuring two traffic lines instead of one. The third table operates Sayville, which may be working with the station on top of Admiral Sims' office in London. Tuckerton is operated from the fourth table, and may be used for keeping in touch with Rome or other European capitals and centers. Most important of all, the four stations may be working at once, yet there is no interference because of the perfect syntony or tune of the transmitters and receivers.

In order to speed up traffic, especially in the case of press dispatches and similar voluminous matter, the radio messages are sent by means of perforated paper tape. An operator, sitting before a machine which resembles nothing so much as a typewriter, perforates a paper tape by manipulating a keyboard. The paper tape, in turn, can be reeled through an automatic sending machine at the rate of 100 words per minute, as compared with the usual 25 words a minute of hand sending. At the receiving end, a special photographic form of recorder, which employs the string galvanometer and a beam of light principle, records the high speed messages on a tape which can be decoded in the operator's own good time.

It has been said of aviation that the war gave it at least a 10-year gain in development and application. But in this respect aviation is not unique; for, to all appearances, American radio communication has made an equal advance as a result of serving its country and the Allied cause.

THE PROBLEM OF KEEPING IN TOUCH

How Armies Communicated Between Companies, Regiments and Headquarters, with Particular Reference to the U. S. Army

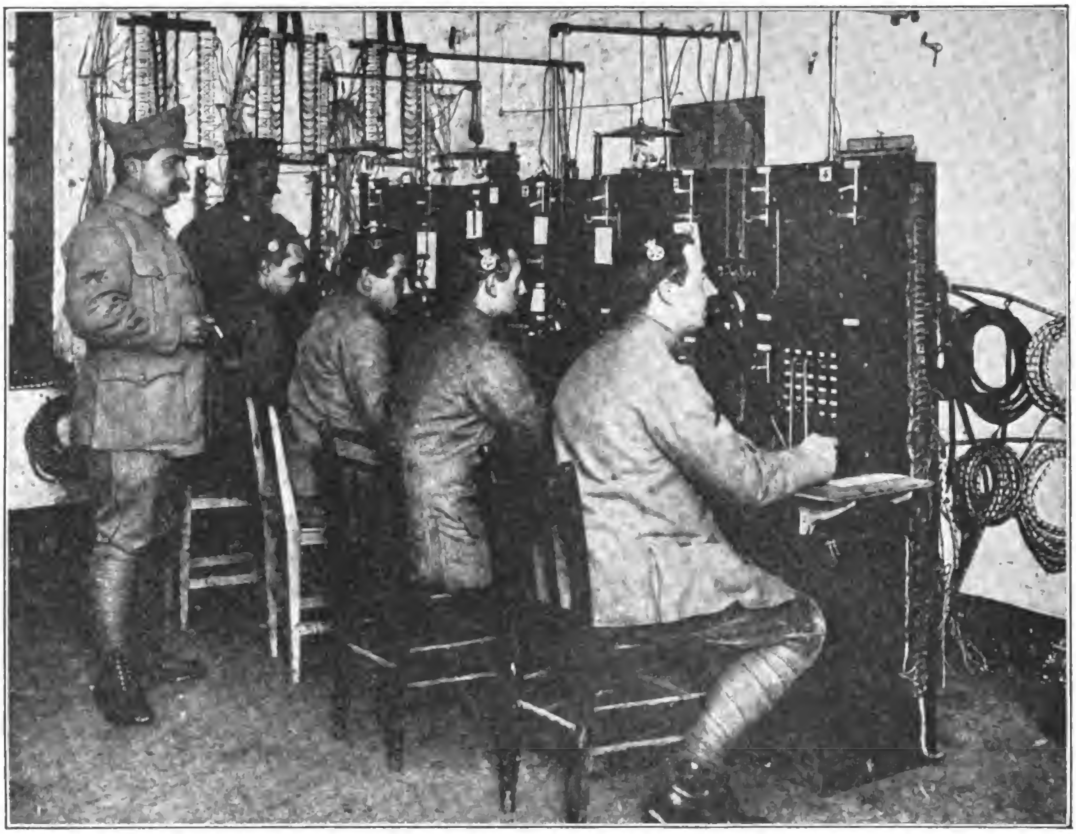
UNTIL after the Civil War, the operation of large units of troops was greatly handicapped by the limitations of military signaling as then known. A force could not be effective in combat that could not be readily reached in all quarters by runners or riders or by visual signals. The development of the telegraph and telephone and the invention of wireless changed all this, so that in the great war armies extended out on fronts 100 miles or more in length with every part of them in immediate touch with every other part through the exact and complete system of signaling on the field.

Military signals to-day include the telephone, the telegraph, radio telegraphy and telephony, the buzzer, the buzzerphone, panels, pyrotechnics, flags, smoke signals, pigeons, dogs, mounted orderlies, and runners. The Germans even had a specially constructed shell for shooting messages to a point which could not be reached otherwise. Each of these means of signaling is an adjunct to the others; when one fails, another is employed to get the message through. Some have special uses for branches of the service with peculiar requirements. The radio telephone is especially suited for communicating from airplanes. Artillery fire is directed by wire and wireless communication. Trained pigeons are sometimes able to get messages through when all other means of communication have failed.

The Army did not have a great quantity of signaling equipment when it came to war with Germany, but what it did have was good. The American punitive expedition in Mexico, where long lines of communication over rugged country were required, had given opportunity for testing modern signaling apparatus in the field. Many of the signaling devices used by the American Expeditionary Forces were, at least in type, in common use

by the civilian population; yet the procurement of this equipment offered heavy difficulties. This was because the Army was much more exacting than was commercial demand as to the quality of material used. For instance, a telephone instrument for use in the field hardly can be compared with the telephone in the business man's private office. The field set demands stronger connections, better insulation against the dampness of outdoor work, and more rugged construction to withstand rough usage by an army on the march.

One of the larger tasks of the Signal Corps in France was that of providing facilities for communication for the Service of Supply. The first Signal Corps officers sent to France soon realized that the forthcoming American Army could not depend upon the French telegraph and telephone systems in the various zones of operation, because those systems were already overburdened by the uses of the French Government. Consequently, it became necessary to set up our own telegraph and telephone systems, extending them from the ports of debarkation through the various bases and zones up to the battle regions. The magnitude of the system which finally was constructed is shown by the fact that on November 11th, the date of the armistice, there were in France 96,000 miles of American telegraph and long-distance telephone circuits. This wire was all used by the Service of Supply and by the various Army bases behind the front.



Telephone Central at French Army Headquarters

TELEPHONE SYSTEMS IN NO MAN'S LAND

Yet in the field of fighting the requirements for wire were even greater. At one time during the height of the operations it was evident that the time was not far distant when the Signal Corps would need 68,000

miles a month of what was known as outpost wire, for use simply in connecting up the telephone and telegraph systems carried along by the troops in their advances.

Outpost wire was entirely a development of the war against Germany. The original telephone system used at the front had been the single telephone wire grounded to complete the circuit. But all the armies in France perfected their listening instruments to such a degree that they could hear conversations conducted on the grounded telephone circuits, the sounds being detected in the earth itself. Consequently, it became necessary to carry forward with troops two-wire telephone circuits, thus doing away with ground connections. Even then care had to be taken that the insulation of this double wire was perfected, lest the impulses enter the ground through gaps in the insulation. Wireless for outpost communication was equally impracticable, since the enemy could easily listen in and hear the radio telephone messages.

Outpost wire insured secret communication at the front. Outpost wire was a twist of two wires, each single wire being made up of seven fine wires, four of them of bronze, and three of them of hard carbon steel. These were stranded together, coated, first with rubber and then with cotton yarn, and finally paraffined. The wire was produced in six colors—red, yellow, green, brown, black, and gray—for easy identification in the field, each unit employing its own color.

The wasteage of outpost wire was enormous. In an advancing movement it was folly to undertake to pick up the wire. The abandoned miles of it had to be left in the field to be salvaged later by the clean-up parties.

The proposition of producing 68,000 miles of outpost wire every month staggered the wire manufacturers of the country. There were not enough braiding machines to complete such an order, and new ones had to be built before such a quantity of outpost wire could be attained. And this is but one item. In addition to the various means of communication, the Signal Corps was also called upon to supply in large quantities such other articles as wire reel carts, flag staffs, field glasses, photographic equipment, chests, tools, meteorological apparatus, wrist watches and various other items.

The work of our own Signal Corps is here described, but it must not be forgotten that our Allies and the Germans carried out work of no less magnitude in keeping their armies provided with "nerves"; for such, indeed, are the telegraph and telephone lines and radio apparatus and wigwags of the signaling department of any army.

OUR TELEPHONE SYSTEM IN FRANCE

At the signing of the armistice there were 282 American telephone exchanges in France, with 14,956 telephone lines reaching 8,959 stations. The 282 exchanges ranged from the small four-line monocord unit, such as can be seen in any business office, to the standard American multiple board of the city telephone exchange. Of these latter there were over 30 in use by the American Expeditionary Forces when the armistice was signed.

The special telephones adopted for use in the field were different from any in commercial use in America. The Signal Corps had developed certain special instruments combining both telephone and telegraphic principles. The field telephone, model 1917, for instance, was a telephone which included a telegraph buzzer on its telephone circuit. This instrument was used when great secrecy in communication was required. The messages were sent in telegraphic code, the buzzers being heard by the receiver. Another instrument was known simply as the buzzer. This was an instrument which utilized the telephone receiver for telegraphic messages. It was a supreme development for use over defective lines. An instrument closely related to the buzzer, but which gave even greater secrecy, was known as the buzzerphone. The buzzerphone was put into production just before the close of hostilities.

The mobile switchboard in most general use by our troops at the front was developed originally by the army and was known as the monotype. It was designed in units and could be extended to accommodate up to 12 trunk lines leading away from the board. This apparatus was the "central" of the front-line dugouts. It could be put into operation in a few minutes and was easily carried by a soldier.

The switchboard of the dugouts was the only telephone equipment not of American design used by the American Expeditionary Forces. It was put into production in the autumn of 1917 in three American plants, under the general policy of the Signal Corps to contract with more than one factory for the production of any important device.

Another type of field switchboard when packed for transit resembled a salesman's trunk. It was used in the camps and provided for 40 lines. This board was being constantly redesigned as field needs developed. A new type of camp switchboard was coming into heavy production at the end of hostilities.

The telegraph apparatus of the lines of communication in the S. O. S. was designed along purely commercial lines. It included the latest type of printing telegraph equipment, the apparatus first adopted being the multiplex printing telegraphy as used by the Western Union Telegraph Company. Later, the Morkum printing telegraph was adopted.

At the close of hostilities 133 complete telegraph stations with full equipment were in operation in the Service of Supply. The peak load of this service, just prior to the armistice, was 47,555 telegrams averaging 60 words each, sent from these stations in a single day. The daily average in the final weeks of the fighting was 43,845 telegrams. And as for the women—we would need a separate chapter to tell about that.

LINE EQUIPMENT OF THE SIGNAL CORPS

The first requisition for line equipment for France called for the construction of 500 miles of telephone and telegraph main pole lines, carrying 10 copper telephone and telegraph wires. It was found that ship space could not be spared for poles in such quantity. Consequently a forestry unit was sent to France to get these poles from the French woodlands. All of the other materials for the 500 miles of line, together with materials for approximately 600 miles of extensions, were procured in the United States and shipped to France within six months after the requisition was received. This material was secured in such short time only by the coöperation of the large commercial companies in the United States, who literally stripped their warehouses bare of their supplies.

In the late summer of 1918 the American Government began anticipating the advance of the Allied forces into Germany, and the Signal Corps put into production a reserve equipment for long-distance line approximating 500 miles. Soon there was received from France a cablegram asking for the shipment of this material, and it was all floated before the armistice. However, as it turned out, this equipment was never required, since the terms of the armistice gave the American forces the German telephone and telegraph lines in the occupied territory.

Signal Corps Photo.

Starting a Smoke Screen

This line equipment was all of a type standard in the United States. For the fighting zone special line equipment was required. Before the war with Germany, American signal troops had set up their emergency telephone and telegraph lines on the standard "lance poles." These poles served admirably in open warfare, but proved to be impracticable for the static conditions of fighting in France. After a considerable supply of lance poles had been shipped abroad their production was curtailed. Thereafter the trench telephone and telegraph line was supported on short stakes with special cross arms,

in appearance the conventional telegraph poles in miniature. The enormous mileage of trench lines called for a great quantity of insulators and cross arms. The wastage of these fittings, due to their being exposed to shell fire, became increasingly greater in the closing months of the war.

As the fighting grew more intense and covered a wider and wider area, the waste of outpost wire also became enormous. The demand of our forces for cable dropped to a negligible quantity, but wire requirements rose. Outpost wire became the main dependence of ourselves and the Allies for all communication in the active sectors. As a substitute for outpost wire to fill the immediate needs the familiar twisted drop wire, with which the ordinary telephone is connected with the main circuit, was adopted. Our field officers liked drop wire, its only objectionable feature being its relative bulk. All available drop wire in the United States was shipped across and its manufacture was pushed until the new type of outpost wire could be produced.

The American Expeditionary Forces consumed likewise great quantities of electric batteries, the familiar dry cell of commerce being most used. Toward the end of the fighting arrangements were being made to establish in France a plant at which dry batteries would be assembled by French labor, utilizing parts made in America. The necessary apparatus and materials for the first operation had reached France prior to the armistice, but the plant was not in production at that time.

Storage-battery requirements of the American Expeditionary Forces were heavy and exacting. The storage battery was the only practicable source of electrical energy for the operation of small portable radio outfits. Field conditions required a storage battery that could not spill its contents, with a jar not easily broken, the whole equipment being as light as possible. A rubber composition jar was finally adopted.

The chief reliance of the American Expeditionary Forces was in storage batteries of European manufacture, which were to be used until American production got under way. When by the summer of 1918 America had perfected her own designs of radio equipment, the Signal Corps took up the matter of storage batteries for radio and decided upon types. This was in July, 1918. A conference of battery manufacturers was called and orders were allocated among practically all the storage-battery plants in the United States that were in a position to undertake quantity production. The end of hostilities stopped this production on the eve of heavy deliveries.

LONG-DISTANCE EYES

When the war began, the Signal Corps had the duty of providing field glasses for all branches of the Army, issuing them to non-commissioned officers and selling them at cost to commissioned officers engaged in combat. The first estimates showed that these glasses would be needed by the tens of thousands, whereas the manufacturing facilities in the United States had turned them out merely by the hundreds.

The optical-glass industry had never been developed in America, our field glasses being supplied with lenses of European glass, and principally German glass. In 1914 the imports of optical glass were $641,000 in value. The following year they were almost nothing. The advance of the German army toward Paris encompassed the glass plants of Belgium and many of those of France. England needed the entire output of her own glass factories.

In the autumn of 1914 the American optical-instrument makers began to develop an optical-glass industry, largely stimulated by the possibility of obtaining heavy orders at high prices from the British, French and Russian Governments. They were aided by the United States Bureau of Standards and by the geophysical laboratory at the Carnegie Institution. The Bureau of Standards established a laboratory at Pittsburgh where experiments were conducted with 30-pound pots of glass.

Optical glass differs greatly from ordinary glass. It must be clear, without striae, and there must be no strains in it from the final stirring and cooling. It must give a high transmission of light.

In addition to the difficulties surrounding the glass supply, there was only a limited number of establishments capable of manufac-

turing field glasses after the glass was procured. These concerns were located principally in Rochester, N. Y., where they had been manufacturing a wide variety of optical instruments, including opera glasses, camera lenses, scientific and educational apparatus, battery commanders' telescopes, marine glasses, microscopes, and gun sights. In order to meet the war requirements of America for field glasses, these factories had to install large quantities of new equipment and to run day and night. The equipment consisted of lens-grinding apparatus, lathes, dies, and automatic screw machinery.

Out of a situation that seemed impossible at the outset the Signal Corps built up an industry within a comparatively few months which provided all the field glasses that were necessary in the operations of the American Expeditionary Forces. Often to keep the optical factories equipped with sufficient workmen the Signal Corps obtained the furlough of drafted men with experience in this line so that they might go to work making field glasses.

All Army organizations except artillery were supplied with a six-power glass having an angular field that took in a view 150 yards wide at a distance of 1,000 yards. The glasses were of the prismatic type with individual focus for each eye. Each glass was provided with a leather carrying case and shoulder strap. On the top of the case a compass was mounted. Artillery organizations were supplied with eight-power field glasses, all of which were purchased in France. The total requirements of the American Expeditionary Forces for field glasses of the six-power type during the period of hostilities were approximately 100,000 pairs. The total shipments from America were 106,000 pairs.

The Signal Corps also took up the matter of providing wrist watches for the Army. A 7-jewel movement was adopted as standard for issue to troops and a 15-jewel movement was adopted as standard for sale to officers. A waterproof case was adopted, bearing the serial number of the movement on the outside, the case being so constructed as to require a special tool to gain access to the movement.

British Official. Underwood and Underwood.

One Way of Sending an S O S

A British officer in a submarine fixing a message to the leg of a pigeon.

LITTLE-KNOWN ACTIVITIES OF THE SIGNAL CORPS

A total of 2,402 tool chests for the Signal Corps was produced during the war period. The plan eventually adopted was to split up the orders for tools among the various manufacturers and to give the manufacture of the empty chests to prison labor at Fort Leavenworth, where the tools were to be shipped and packed in the chests. This plan, however, required the construction of a special building at Fort Leavenworth, and in the meantime the assembling of tool chests was conducted at the Signal Corps supply depot at Philadelphia and at the port of embarkation. The armistice stopped the construction of the assembling factory at Fort Leavenworth.

The Signal Corps produced a suitable number of gas alarm signals known as strombos horns. This equipment consisted of an alarm horn operated by air pressure acting against a diaphragm and thereby producing a loud and distinct chatter. Compressed air was supplied in small steel cylinders connected to each horn by hose. The air tanks were charged behind the lines from a portable air compressor which could pump into several cylinders at once.

Flag kites were not used to any great extent by the American Expeditionary Forces, although large quantities of these were produced in this country.

British Official. Underwood and Underwood.

A Feathered Warrior

British pilot releasing a pigeon with a message for help. Many lives were saved in this way during the World War.

OUR WINGED COURIERS

Although nearly every European Army for forty years has trained the carrier pigeon to be a field messenger, the American Army never adopted the bird until 1917. In a single year the Signal Corps established hundred of pigeon lofts in this country for service in France. In actual use on the field the pigeons delivered more than 95 per cent of the mes-

sages intrusted to them, flying safely through the heaviest shell and gas barrages.

The standard pigeon loft adopted by the Signal Corps had a unique trap arrangement which permitted the entry but not the exit of returning pigeons, and an electrical alarm which automatically notified the attendants of an arrival. Such lofts, however, were of the stationary type and not practicable for use in France. For the American Expeditionary Forces the Signal Corps purchased mobile lofts. It was found that pigeons would come home as well to mobile lofts, which were constantly changing position, as they would to stationary lofts. The first mobile lofts built in the United States were top-heavy, but this defect was overcome by increasing their width and adding heavier wheels. They were all built by a trailer maker in the Middle West.

Civilian pigeon fanciers were appealed to and urged to breed young birds to stock the government lofts. The Signal Corps distributed small aluminum bands to be put on the legs of squeakers, as the newly-hatched pigeons are called, which were intended for sale to the government. The uniform price of $2.00 per bird was paid, and over 10,000 youngsters were bought for stocking purposes.

Tons of pigeon feed were purchased and shipped to Europe. Some of this grain, such as millet, Argentine corn, pop-corn, hemp seed, and Canada peas, was hard to obtain; but nevertheless the supply was well maintained. It was shipped in hermetically sealed containers to prevent it from becoming mildewed.

The American Army copied the French and British models of willow and reed baskets to hold the birds. Only one type of basket was carried on the back of the soldier and contained small corselets in which the pigeons were securely fastened. Corselets were suspended from the sides of the basket by elastic contrivances permitting considerable joggling without injury to the birds.

PHOTOGRAPHING THE WAR

How the Various Armies and Particularly the American Army Made Pictorial Histories and Daily Maps of the Great War

PHOTOGRAPHY has had a great part to play in the war, and has been a very vital factor in almost all military operations. The work of the aerial photographer and those who develop and print his work in record time, that artillery or other officer may have the data thus obtained, has added a new laurel to the crown worn by Daguerre.

But now that the war is over and as time heals the scars on the terrain, and industry and patriotism unite to rebuild the shattered buildings, photography will be longest remembered in connection with the war for its preservation of sights and scenes which must soon disappear, and pass from the recollection of living men.

HISTORIANS WHO WRITE WITH CAMERAS

Both French and English Governments have made very complete pictorial histories of their parts in the great conflict. Luckily for both the historian and the military authority, the United States had, in the Signal Corps, an organization able to cope with the far-flung activities of America in Europe. And if our collection of photographs compares favorably with those of other countries, if our "movie" films of the war will bear viewing side by side with those of France and England, and if our military authorities can prove a point or build up a new science of war in the future because of the existing pictures, it will be because the photographic division of Signal Corps was very much on the job.

The United States entered the war April 6, 1917. On July 27th of the same year the first Signal Corps photographic laboratory was located, in the plant of a film company, just outside of Paris. Its personnel consisted of one officer and one private.

The Laboratory and Photographic Division,

as this organization is called, was formed not only to compile a complete pictorial history of the American participation in the war, but to assist in supplying the American periodicals with both news and propaganda pictures. In this connection, it functioned through the Committee on Public Information, but was in no way connected with that body except as the means of supply of the pictures which the Committee distributed.

a sergeant, first class, and a private, first class. One such unit was attached to every division, every corps and every army headquarters in France, and as many as were needed were stationed in England, Italy and Russia.

These units did both "movie" and still work, often under fire, often at the front, but, as well, behind the lines, in the path of both advance and retreat, picturing everything picturable which might be of future or was then

© Underwood and Underwood.

An Example of Communicating Trenches

Showing war photographers at work.

of present interest. There has been no military movement of any importance that has not been photographed. There is no regiment which has not had its place in the pictorial files. There has been no evidence of American ingenuity in any of the sectors under American control which has not been preserved in picture form.

As might be expected, with the rapid growth of shipments of men, American participation in the war speedily demanded a much more extensive force and much larger quarters for its photographic units. So that in February, 1918, with eight officers and 28 enlisted men, the laboratory moved to a motion-picture plant at Vincennes (just beyond Paris), where more space and better equipment were available.

The work in the field was done by what were known as Photographic Units, in almost every case consisting of a commissioned officer,

The photographic units were composed of trained photographers, men who knew cameras and camera work, and often, as well, men who knew pictures from both the pictorial and the news side. The result has been a really

wonderful collection of pictures, how wonderful no one in America really knows, both because of a lack of adequate distribution machinery for pictures at home, and because of the absence, at the present moment, of any legal method by which these photographs can be made available to the American public, of which anomalous situation more in a moment.

The photographic units had occasionally some strange orders to deal with from swivel chair officers at home, as in the case of the photographer who was solemnly assured at Washington that the engineers, having lumber, would be glad to build him a platform "to one side of a trench" from which elevated viewpoint he might get a good movie view of an attack!

Then there was the officer who made written request for a picture of a battle with certain specified objects much desired to illustrate a lecture-room point. They included a river in the foreground, with troops crossing it under fire, a battery to the left, in action, protecting said troops, and the Boche retreating in the background! Nor are these the only incidents which could be recounted to show the commonness with which the useful and the ornamental functions of the photo service were confused.

As this is written the Photographic Division consists of fifty-four officers and 418 enlisted men and clerks. By no means is the work all finished, and much that could not be obtained during the combat has been made available since, and positions, towns, formations, defenses, etc., are still being photographed. So far the Photographic Division has developed 36,574 still negatives and 594,277 feet of original moving picture negatives. These negatives of both classes are filed and indexed in such a way that any one can be found at almost a moment's notice. For instance, if some one wants to know what the second company of the 6th Regiment of marines did on such and such a date, and a picture was made at that time, it can be found, instantly. Or if some one wants to know what the town of Etain looked like on a certain date, it can be found. If any portrait is wanted it is findable, instantly, if it exists. In other words, everything is cross-indexed and up-to-date so that there is no time lost in getting at the picture when it is wanted.

A MATTER OF SYSTEM

Somewhat the same system exists with regard to the moving picture negatives. They are in small sections, of course, but so classified that on demand any variety of film can be made up. Thus, an artillery authority can have one showing only artillery work, or a medical officer can have one showing only hospital work, or an S. O. S. may get a movie film of any number of reels he pleases devoted entirely to transportation or any other subject, merely by specifying what he wants.

Of the organization of the laboratory it is unnecessary to speak except to say that it gets things done. A personal visit to the laboratory shows a set of soldiers who apparently thoroughly enjoy their work, and who have quarters, food and shelter close to the laboratory which are more than comfortable. The laboratory itself works under high pressure and turns out prints and films as ordered by military authority with surprising speed, but with due regard to photographic permanence.

Mention was made of the curious fact that there is no way by which the American public can get at these photographic records. This is no one's fault, apparently, but simply a lapse or gap between the cessation of function of the Committee on Public Information, which body formerly distributed the war pictures sent it by the Signal Corps, and the creation of some new distribution machinery. It is illegal for the United States Army to sell its property, and it is equally illegal for it to give it away. Photographs here available can only be put forth for official purposes! Inasmuch as one of the reasons why they were made was to show America what her sons did and how they did it, this is a condition which should be, and doubtless will be, changed as soon as Congress is shown that a law to permit some permanent form of distribution of prints is a necessity.

PHOTOGRAPHY THAT SAVED LIVES

In four days of the final drive of the Yankee troops in the Argonne district the American photographic sections of the Air Service made and delivered 100,000 prints from negatives freshly taken from the air above the battle lines. This circumstance is indicative

of the progress made by military intelligence from the days when a commander secured information of the enemy's positions only by sending out patrols, or from spies. The coming of the airplane destroyed practically all possibility for the concealment by day of moving bodies or of military works. Mere observation by the unaided eye of the airmen, however, soon proved inadequate to utilize properly the vantage point of the plane. The insufficient and often crude and inaccurate drawings brought in by the airplane observer were early succeeded by the almost daily photographing of the entire enemy terrain by cameras, which recorded each minute feature far more accurately than the human eye could possibly do. The airplane, to quote the common saying, had become the eye of the Army, but the camera was the eye of the airplane.

This development in military information-getting from start to finish was entirely the product and an evolution of the World War. When the war broke out in 1914 there was no precedent for the military photographer to go by, nor had any specialized apparatus ever been designed by either side for this purpose. As a result the first crude makeshifts were rapidly succeeded by more and more highly developed equipment.

At the outset of the war, before anti-aircraft guns were brought to efficiency, it was possible for the observation planes of the British, the French, and the Germans to fly at low altitudes and take satisfactory pictures with such photographic appliances as were then in common use. But the "Archies," as anti-aircraft guns were called by British airmen, forced the planes to go higher in the air, special equipment had to be designed for longer distance work under the adverse conditions of vibration and speed, such as exist on airplanes. It is a tribute to the photographic technicians of the world that they were able to produce at all times equipment to meet these increasing demands.

As the airplanes moved into higher altitudes, longer focus lenses had to be employed, special dry plates developed, and special color filters provided to overcome the haze created by humidity in the long spaces between the cameras and the ground. When the war ended, cameras were in common use taking photographs at an altitude of four miles with such microscopic fidelity as to show even where a single soldier had recently walked across a field!

For years America had been second to none as a photographic country, and it was to be expected that this country would make notable contributions to the new science. It may indeed be wondered why, with the experimental laboratories and the skilled technicians at our command, we did not start at once to develop our own aerial designs and equipment. Our officers, however, felt that such a course would be likely to duplicate much of the work already done by the Allied countries, who stood ready then to furnish to us the results of their experiences. While original research work might result in the invention here of certain equipment of superlative merit, yet we would be sure, in the course of such an undertaking, to adopt methods which had been tried and discarded by the Allies and which we ourselves would have to discard when experience had proved them to be without value.

The information in our hands in December, 1917, showed that the British system of air photography differed radically from that of the French. The French cameras made a relatively large negative, 18 by 24 centimeters in dimensions, on a glass plate. The magazines of the French cameras held 12 plates, and extra magazines were carried in the plane. These cameras were fitted with lenses or relatively long focus—20 inches. Three operations were necessary to make an exposure. The photographer must change the plate, set the focal plane shutter, and press the release. When the negatives were developed, fixed, washed, and dried, prints were made by contact.

The British used a smaller sized plate, 4 by 5 inches in size. Their cameras were equipped with the only lenses available in England in the early part of the war—lenses of relatively short focus, ranging from 8 to 12 inches in this respect. Instead of making contact prints from these plates, the British made enlargements, measuring 6½ by 8½ inches. In the earlier period of our development of aerial photographic apparatus, we were in the same position as the British as regards lenses. We had no adequate supply of long-focus lenses. Consequently we followed the British designs of cameras and adopted

the British system almost explicitly in the training of aerial photographers.

It had been our first thought to use films to a great extent on the front, since America was the country which had perfected the photographic film, and was therefore, presumably, best equipped in skill to adapt it to war uses. But plates had been used practically exclusively by the British, the French, and the Italians; and it appeared wisest to follow their experience at first, though all agreed that film, with its small bulk and weight, would be greatly superior for airplane use.

OUR PHOTOGRAPHIC EXPERIMENTAL DEPARTMENT

The Photographic Experimental Department of the Air Service, which was organized in January, 1918, had as its major problems the design and test of aerial cameras and all their parts and accessories. Equally important with this problem was that of sensitive plates, papers, color filters, and photographic chemicals. The corps of photographic and optical experts, into whose hands these matters were placed, early secured the active coöperation of the chief manufacturers of photographic apparatus and materials in this country. In the laboratories in Washington, D. C., Langley Field, Va., and Rochester, N. Y., comprehensive development work was inaugurated, leading ultimately to perfection of new designs of cameras and the development of plates and other photographic materials equal or superior to any available abroad.

The first airplane camera which it was decided to put into production in America was a close copy of the British type "L," which had proved to be one of the best mechanisms employed at the front. The operation of this camera was semi-automatic, the operator having only to press the shutter release to keep the camera at work. The operating power was derived from a small windmill or air propeller driven by the rush of air past the plane. The automatic mechanism changed the plate and set the shutter after each exposure. Because of the situation with respect to the lenses these cameras were constructed to use lenses of 8-inch to 12-inch focus, and the English 4 by 5 plate. Some 750 of these cameras were constructed. They played an indispensable part in the training of nearly 3,000 aerial photographers in this country. They were also used by our bombing squadrons at the front.

At the same time it was generally agreed that we should plan to follow the French practice as soon as lenses of greater focal length could be manufactured in this country. Increase in focal length was becoming imperative, because aerial photographers were being compelled to make exposures from much greater heights than in the earlier part of the war. For the sake of those unacquainted with photography it may be stated here that lenses of short focal lengths will not record the details of objects a great distance away from the camera, the longer-focus, rarer, and more expensive lenses being required for distance work.

As a basis for the design of cameras of longer focus a sample of the 20-inch focus camera used by the French had been sent to this country by the American Expeditionary Forces. The first camera authorized of this focal length was similar in general character to this French camera. It was constructed on the unit system, each part—shutter, camera body, lens cone, and magazine—being of standardized dimensions. It was understood that these standard dimensions were to be followed in all subsequent cameras both in this country and in the countries of the Allies.

The idea constantly put before all designers of aerial cameras has been that of the automatic type, in the use of which the observer or pilot will have a minimum of work. Late in 1917 the Photographic Section of the Air Service, American Expeditionary Forces, secured the rights for the manufacture of an ingenious design of automatic plate camera invented by Lieut. DeRam, of the French Army, and requested that this be put in production. In this camera the magazine, which carries 50 plates, 18 by 24 centimeters in size, rotates between each exposure, while the exposed plate is removed from the front of the pile and carried to the back. After some study here of the incomplete model, this camera was redesigned in such form as to fit it for methods of American manufacture. It was made semi-automatic in operation; that is, the work of the observer or pilot consisted merely in releasing the shutter at will, a fresh plate always being in place. At the

time of the armistice 200 of these cameras were rapidly approaching completion.

Meanwhile experiments were actively pushed in the matter of the utilization of film. Various difficulties and problems had to be solved before the film could be considered practical. Considerable time was consumed in overcoming the peculiar static electrical discharges which occur on film in cold, dry regions, such as in high mountains or the upper atmosphere, and fog the sensitive surface by their light. The film camera finally decided upon was based on the fundamental design of a well-known camera company.

This camera, know as the "K" type, carries a film on which 100 exposures, 18 by 24 centimeters in dimension, can be made at one loading. The film is held flat by an ingenious device. The film strip passes over a flat perforated sheet behind which a partial vacuum is set up by a suction, or "Venturi," tube extending outside the body of the airplane. The camera is entirely automatic, and is driven either by a wind turbine of adjustable aperture, or, in war planes, by electric current from the heating and lighting circuit. The observer in the airplane needs only to start the camera and regulate its speed according to the speed with which the airplane is passing over the ground below, and the camera therefore will, of itself, take pictures at such intervals as to map completely the terrain under observation.

PROBLEMS AND STILL GREATER PROBLEMS

In conjunction with the use of film in cameras came the question of handling the film in the dark room; that is, the ordinary manipulations of developing, fixing, washing, and drying—a serious problem when the large dimensions of the film, its length, and difficult characteristics in handling are taken into consideration. This problem was attacked and a film developing, handling, and drying machine was produced.

Some 200 of these automatic film cameras were on order at the close of the war. Altogether, over 1,100 airplane cameras of all types had been and were about to be delivered when the armistice came.

One of the most serious problems in aerial photography is the proper mounting of the camera in the plane. Not only does the plane travel at great speed, which makes necessary exceedingly short exposures and therefore highly sensitive photographic materials, but the motor causes a continuous vibration which, communicated to the camera itself, would be fatal to obtaining sharp pictures.

The experimenters of the Air Service carried out a long, extensive, and most interesting investigation at Langley Field to make clear the whole question of preventing the vibration of the airplane camera. The scientists worked out a method of making the camera itself record the vibrations communicated to it by the plane when the box was not held by a proper vibration-neutralizing suspension.

The plan adopted was to send up a camera thus mounted on an airplane, focus it on a light on the ground below, open the shutter, and take a time exposure from the swiftly-moving plane. The result, of course, was a stream, or trail, written on the plate by the point of light below, the jagged or wavy character of this trail indicating the vibrations of the camera and determining the proper principles of a suitable mounting.

The first thought was to do this work at night, as the British had done, when the light below would pierce the darkness distinctly. But night flying is hazardous, and a better plan was called for. Nor would the proposal to use an extremely strong light in broad daylight do, because, while the light would indeed be photographed continuously across the plate, so also would the surrounding ground, and the general result would be a fogging or blurring of the outlines of the streak.

Finally the problem was solved by conducting the aerial experimental work over woodland in the late afternoon. A strong, reddish light was placed in the woods so as to be visible from above. The surrounding green foliage supplied a frame of sufficient contrast to the light to make its impression distinct on the plate. To emphasize the contrast, the camera lens was covered with a reddish colored ray filter, and this brought out sharply the outline of the streak.

These tests resulted in the design and production of new and unique camera mountings which successfully stopped all vibrations of the camera.

A problem on which it was necessary to

have the closest coöperation of the plane designers was that of installing the large 20-inch focus cameras in the airplane. There is little room at best in a plane, and the demands for armament, wireless, and bombing space all had to receive attention. In the American service a distinct advance was made in the design of a special plane intended primarily for photographic reconnaissance. Several of the planes, which were the most completely equipped for photographic purposes of any designed during the war, were built and would have been put into quantity production late in 1918.

Parallel with this development of apparatus went studies of the sensitive materials and methods of photography from the air. Because of the swift motion of the plane extremely short exposures are imperative. Consequently, the most advanced technique of instantaneous photography had to be applied. The coöperation of various plate manufacturers was obtained, who brought out especially for the government several new plates which showed on test to be superior to any which had appeared in the war on either side.

As an airplane rises higher and higher in the sky, the moisture of the intervening atmosphere between the machine and the ground creates a haze which makes aerial photography above a certain height unsatisfactory and even impossible with the naked lenses as used on the ground. The problem of finding the best means for piercing aerial haze occupied the attention of a corps of experts working both in the laboratory and in the field. The solution lay in the use of special color filters of general yellow hue, which obscured the bluish light characteristic of haze. Filters of new materials specially adapted to airplane use were made available as a result of this study.

Field equipment of quite new and special design for performing photographic operations had to be designed and built. Among the most interesting of these developments was the photographic truck or mobile photographic laboratory. This consisted of a specially designed truck and trailer containing all the equipment necessary for the rapid production of prints in the field. The truck body was equipped with a dynamo for furnishing the electrical current required for lights and drying fans, while each unit was provided with an acetylene generator for emergency use, if the electrical apparatus should break down. The mobile dark room carried on the trailer of each unit was equipped with tanks, enlarging camera, printing boxes, and other necessary apparatus. In all, some 75 of these field laboratories were constructed.

While the development of apparatus and new materials was from a popular standpoint in many ways the most interesting phase of the work of the photographic scientists, nevertheless it should be remembered that the great problem in this, as in all other fields of American endeavor, was to produce the supplies in tremendous quantities. In October, 1918, we shipped overseas 1,500,000 sheets of photographic printing paper, 300,000 dry plates, and 20,000 rolls of film. We also sent 20 tons of photographic chemicals. These were merely the principal items in the consignment. Besides paper, plates and chemicals, the field force required developing tents, trays, printing machines, stereoscopes, and traveling dark rooms, to name only some of the principal items. Much of the material already on the market was not suitable for the purpose, a fact requiring the production of specially manufactured supplies.

LANDING IN THE DARK

Few things are more helpless than an aviator trying to make a landing in the dark. Even with an illuminated field, he may have the greatest difficulty in coming down in the right direction on to the right spot. To aid him in this, the French devised a clever signal light. It consists of two large circular frames, parallel but not in the same plane —arranged rather coaxially, like the upper and lower rims of a drinking glass or a piece of pipe. These frames carried a series of lights close together, making them look like continuous rings of fire. They were so arranged that the aviator, in making a proper landing, must fly directly toward them; and when he did this, at the proper altitude, he saw one fiery ring cleanly inside the other. If one came above the other or to one side, or if the inner one cut the outer one at all, he knew he was off his landing course and would swerve up or down or to one side to correct his error.

CAMOUFLAGE—THE ART OF MILITARY DECEPTION

Some of the Weird Things Done on Land and Sea to Deceive the Ever-Watchful Enemy and Make His Fire Less Effective

A PRESENT-DAY high velocity gun of 16-inch bore fires a shell weighing 2,400 pounds a distance of 27½ miles. The shell, which weighs as much as a five-passenger automobile, is capable of penetrating 12 inches of battle ship armor at all ranges; or it will penetrate a wall made up of 40 inches of compound steel armor, 16 inches of wrought iron, 40 feet of oak timbers, 10 feet of granite, 22 feet of concrete, and 12 feet of brick wall, making a total of 88 feet.

What chance has a fort in these days of powerful artillery? To attempt to resist siege artillery is now hopeless, as is attested by the fate of such first-class fortresses as Liége and Antwerp, which gun-fire converted into shapeless, chaotic masses of broken stone and twisted steel. How can one establish a defense in the face of such formidable weapons of offense?

The one chance that is left is that the shell will not find its mark. And to prevent it from finding its mark is the strategy of all warfare of the present. No longer is a target in the shape of a powerful fortress flaunted before the enemy, for if it were it would not last very long in the face of his guns.

TAKING A PAGE FROM NATURE'S OWN TEXT-BOOK

In Nature the soldier finds a striking analogy of the present state of things. There are animals which have not been provided with proper means of defense, and when once discovered are easy prey for those who feed upon them. There are caterpillars and butterflies, for instance, which have absolutely no power to resist the onslaught of the tiniest of birds; lizards which have neither sufficient rapidity of movement nor strength to prevent their becoming an appetizing meal for a larger animal; and giraffes—those ungainly animals which are too docile even to think of fighting.

Yet Nature has provided for all of these. Knowing their inherent weakness, she has provided each with means whereby it becomes more or less concealed from its enemies. Thus caterpillars and butterflies are dressed in variegated hues which tend to confuse the birds which live on them; indeed, in some instances, these insects are formed and colored so as to resemble leaves. Certain lizards have protective color schemes which cause them to blend with the backgrounds of their habitat, and in some instances, particularly in that of the chameleon, the reptile can momentarily change its color in conformity with its surroundings. The giraffe is provided with a quaint diamond pattern which blends with the flickering lights among the acacia trees on which it feeds.

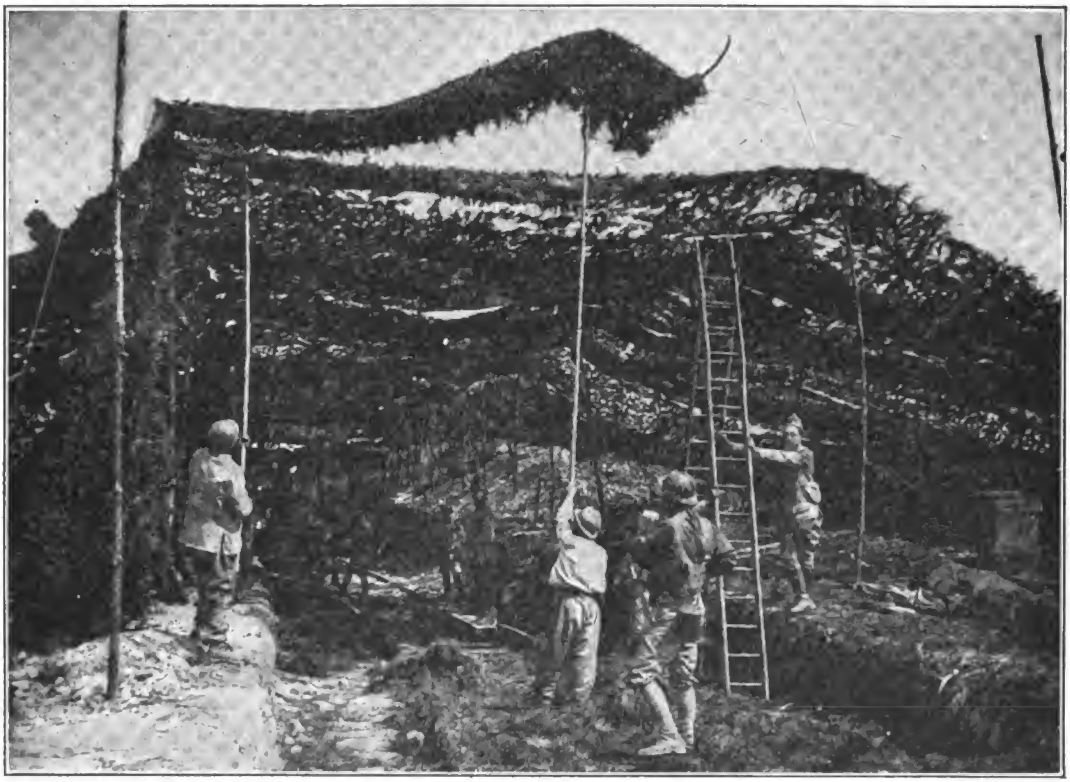
Quite logically the soldier took a page from Nature's handbook. If animals incapable of withstanding the enemy's onslaught sought protection by practicing deception and concealment, why couldn't the same principle be applied to foiling the domineering artillery of battle?

The practice of deception, concealment, make-up or whatever you please to call it, gained rapidly with both sides in the recent conflict. It was at about the same time of the battle of the Somme, during the summer of 1916, that this art assumed gigantic proportions and the term "camouflage," borrowed from the French, became a universal expression. The British and French armies, and most likely the German, Austrian and

other enemy armies, set aside a certain number of men for the practice of camouflage. Artists, scene painters, carpenters and mechanics were impressed into the camouflage service and in short order became expert "camoufleurs."

Nothing has been of greater assistance to the all-powerful artillery than the airplane. Queer combination this, to be sure; the steel monster, belching fire and hurling thousands of pounds of steel and high explosive, works hand in hand with the frail wood and linen airplane which goes about its work in the most graceful of manners. Yet, carrying the observer over enemy territory, the airplane enables the aiming of long-range artillery with a remarkable degree of accuracy. By means of wireless telegraphy, the aerial observer can signal back to his artillery chief the exact position of the target; and as the shells come over and strike he can signal back whether they are falling too long or too short, and how far to either side, until after a number of rounds the shells register on the target.

It is the eagle-eyed air scout against whom camouflage must be employed. For from his lofty perch everything is open to him, just as to a visitor at an exposition every detail of a model landscape is sharply delineated. The landscape below appears in the form of a relief map, with variegated patches indicating different kinds of terrain such as marshes, fields, woods, lakes and hills. Trenches plainly show as dark or light, while roads appear as ribbons of gray or yellow.



Courtesy of Scientific American.

French Soldiers Erecting a Camouflage Screen Over a Railroad Near the Front Lines

MAKING THINGS LOOK LIKE SOMETHING ELSE

But camouflage foils the airman. Batteries are covered with branches and with reed screens until they take on the appearance of the surrounding fields or woods. Ammunition

© *Underwood and Underwood.*

A Soldier in Uniform Standing Against a Tree

Note how plainly he can be distinguished.

The Same Soldier in a Suit of Camouflage

That blends with the coloring of the tree.

dumps are covered with canvas painted to simulate brown soil or the green of the field. Tents when used are painted with a patchwork design which breaks up the outlines so that they blend with the surrounding landscape. Trenches are provided with light screens so as to eliminate sharp shadows, and in some cases are covered over with reeds and foliage. Roads are spanned by reed or canvas screens which prevent the airman from observing traffic. All these things and a thousand more are done to fool the airman, until he has at last accepted the creed of the multitude, "You never can tell!"

In order to make trenches less conspicuous particular attention is paid to shadows. What makes aerial observation so effective is the oblique lighting of sunrise or sunset, for then the sun's rays cast long and sharp shadows which accentuate all objects which, with overhead lighting, would hardly show. Oblique lighting makes for high relief, and consequently more effective observation. To this end it is now common practice to make use of screens for eliminating shadows. These screens generally consist of narrow strips of cheesecloth supported on wooden stakes in front of the trenches, so that the direct rays of the sun cannot fall on the trenches and throw a sharp shadow. Instead, only a diffused, shadowless light strikes the earthwork. The cheesecloth screen, in turn, is of such color and size as to be unnoticeable.

Buildings may have to be guarded against shadows. What would be excellent camouflage at sunrise is totally ineffective at noon and at sunset, so that camouflage is a sunrise to sunset proposition. Generally, unless the camouflaged object is of paramount importance and is receiving undue attention on the part of the enemy, a happy medium is decided upon and the camouflage is an average one for the entire day. Such steps as lightening dark sides of buildings and darkening light sides, in order to average up or distribute more or less evenly the light on all sides, is a common feature of camouflage.

The use of reeds and foliage is perhaps the most common form of battlefield make-up. Almost everything can be protected by a layer of well arranged reeds or foliage or sod, and the majority of guns are protected in this manner so that they can fire from their retreats without betraying their location. Thousands of shells are left in the open behind the lines. A bomb dropped by an airman would cause them to blow up in one terrific explosion; but a suitable covering of reeds or foliage or painted canvas prevents the airman from discovering the ammunition dump.

Spotted camouflage is quite effective in breaking up the outlines of any object. For instance, in the case of large guns mounted on railroad carriages, the usual camouflage consists of a leopard-like coat of paint. Variegated splotches of paint break up the stern lines of the gun so that at a distance it melts into the surrounding landscape, or at least appears as a mystifying, shapeless mass. The spotted form of camouflage is mostly employed where other means are unavailable, and simple as it may seem it proved quite effective in the recent war.

THE EYE THAT IS HARD TO FOOL

If it were not for the aerial camera, camouflage would be a simple matter in so far as the airman is concerned. But by degrees the airman has perfected his photographic apparatus to a point where it tells him many things which would escape his notice if he depended solely on his eyes.

Aerial cameras now make perfect photographs of the ground below them even when flying at altitudes of 5,000 feet and more. The photographs, when developed and printed, are carefully studied by "photographic readers" at headquarters, and there is very little, indeed, that escapes the notice of these highly trained specialists. A little spot which would pass unnoticed through the hands of the average man is detected by the "reader" and made out as a new pill-box or small blockhouse. A slight shadow in front of a section of trench indicates a cylinder of gas for a contemplated poison-cloud attack, no doubt. A dark splotch to one side of the picture indicates that the enemy has been digging, for freshly turned soil is of a different shade from other soil; and note is made of this fact so that the "heavies," or large guns, can send a few shells in that direction.

Now camouflage is, or rather was, generally made in natural colors, so as to deceive the eye of the airman. But the camera has a

totally different "eye" and responds to a different range of colors. So natural colors camouflage does not deceive the camera to any great extent. Furthermore, both sides in the great war made use of panchromatic plates and yellow filters, thus permitting the camera still further to differentiate between camouflage greens and natural greens, or between false and genuine verdure, since the color screens and color plates can pick out shades with great precision. Again, certain cameras, particularly those of the Germans, were of the stereoscopic variety; that is to say, they have two lenses and operate on the same principle as the human eyes. The reason why we see everything in lifelike form as compared to the flat appearance of ordinary photographs is that we see everything through two eyes. Each eye, obviously, sees the common object from a slightly different angle, and the two in combination give the stereoscopic or relief effect. By means of such cameras the airmen can obtain pictures in high relief. Fake trenches, only a foot or two in depth, plainly show as forgeries on the stereoscopic plates, and guns, pillboxes, listening posts and other hostile establishments stand out clearly.

It is the camera which represents the main obstacle of the camoufleurs. But by clever grouping of photographic and visual camouflage a happy medium is struck. It will ever be a contest between the skill of the camoufleur on the one hand and the wits of the "picture reader" on the other. Fortunately for the former, anti-aircraft gunners prevent the airman from approaching closer than several thousand feet from the camouflaged objects. And this distance is the salvation of the art.

Courtesy of Scientific American.

Naval Guns and Gunners In Service on Land

Many warships were stripped of their guns in order to supply more artillery for the land forces. Here, for instance, is a French naval gun and its crew on the Serbian front. Toward the end of the war the Germans stripped many of their warships of their guns for the Western front.

It is by no means to be assumed that the airman is the only one for whom camouflage is intended. The enemy on the ground and in observation balloons must also be deceived, bewildered and prevented from seeing all he wants to see. For that reason camouflage is also applied in the horizontal plane to foil the eyes of those in the trenches across the way. Listening posts are disguised in a thousand and one ways, and snipers' stations are effectively masked so as not to reveal their occupants engaged in shooting human game. Trench periscopes are made in the form of sandbags, and there are thousands of ways in which the enemy is fooled. Tanks, when going up to

the attack, are backed in a coat of war paint which would have brought hilarious joy to the most taciturn Indian warrior—reds, greens, blues, yellows, pinks. All these hues appear as in a mist on the steel sides of the tanks for camouflage purposes. Gaudy as the camou-

© Underwood and Underwood.

Another Soldier in a Suit of Camouflage

flage is, at a distance it blends into an indistinct neutral gray, and the outlines of the ugly monster are such that one cannot tell where they begin and where they leave off. How, then, in the face of this riot of conflicting and obscuring color, could the German gunners spot their guns?

A CLOAK FOR THE MECHANICAL RATTLESNAKE

Camouflage is the very salvation of the machine gun. This weapon is the most deadly of all the terrible machinery of modern warfare; it is the lurking rattlesnake with leaden venom; it exacts a tremendous toll among the soldiers, so great, in fact, that it is the most dreaded of all. Soldiers who nonchalantly face the roar of heavy artillery and the drone of murderous airplanes, pale at the rat-tat-tat of a solitary machine gun pounding somewhere in the dim distance.

It has therefore come to pass that an army will only attack after all the machine guns in front of it have been accounted for. If a single machine gun is known to be in working order, every cannon within range is turned in its direction in order to destroy it. In truth, a commander to-day does not hesitate to turn his twelve-inch guns on a solitary machine gun post in order to blast it from the face of the earth.

So the machine gun, which forms the backbone of any defense, must be protected, and since steel and concrete are of little avail, its only protection lies in camouflage. Some of the cleverest camouflage is to be found in the concealment of machine guns.

Camouflage has a two-fold function: first, and as already discussed, to protect certain military works through concealment; second, to fool the enemy and draw his fire to fake targets. In the latter case the enemy is made to waste his ammunition and at the same time the real targets near by are untouched.

The most spectacular feats of camouflage have been those in the fake target class. Every army, at some time or another, has dug fake trenches and has constructed entire batteries of fake guns so as to draw enemy fire. At a height of 5,000 or more feet the air scout can be readily deceived; a barrel, a pair of discarded wagon wheels, a few pieces of wood and a few charges of black powder will make the most realistic howitzer; and a trench two feet in depth, manned with dummies, will convince the airmen above that an attack is forming. Thousands of shells are rained on such targets by enemy gunners—thousands of wasted rounds—while the real targets are untouched. It would be very interesting to know just how much ammunition went to waste in

this manner since the beginning of the war, but that is another fact which must forever remain behind the self-pride of all belligerents. At any rate, the aerial camera and the clever "picture reader" have made this form of camouflage increasingly difficult.

Camouflage is not a land war art exclusively; it has its application to marine warfare. As in the case of military camouflage, the naval branch has two broad objects: first, to decrease visibility; second, to confuse or fool the enemy.

ship were lightened and the lightest parts were darkened, so as to produce a better blend with the sky and water. Still another system called for a wave like painting of green, blue and white, so that the outlines of the hull would be lost in those of the surrounding water.

FOILING THE MURDEROUS U-BOATS

All of these systems were tried, and since they continued to be employed it is safe to say they all had merit. But since, through the use of proper color screens or ray filters, the U-boat observers might hit upon a plan that would make the camouflaged ships stand out more prominently than if they were not so decorated, playing right into their hands, as it were, it is obvious that any specific details given out during hostilities would have served to furnish the desired information to the ingenious Hun and in this way increase the toll which he was exacting.


French Official.

French Gun Train—Camouflaged

These are naval guns manned by naval gunners.

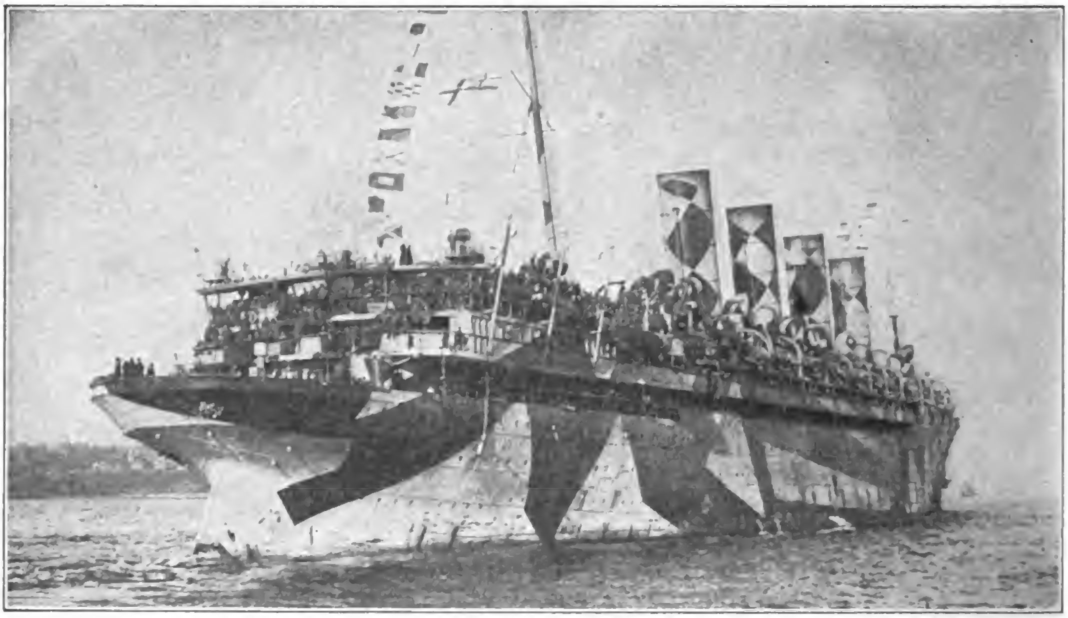
By way of decreasing the visibility of vessels numerous schemes have been tried, but as yet the art is in its infancy. Indeed, during the days of war in American ports there were to be seen large numbers of transatlantic steamships no two of which had the same kind of camouflage.

One system intended to lower the visibility contemplated the use of the primary colors in varied proportions, areas and shapes of areas. This arrangement made for a gray at a distance; a gray, it is said, that was far more effective than the flat war gray formerly employed on battleships. Another system contemplated the reduction or elimination of lights and shadows so that the darkest parts of the

There is no doubt that much can be done to lower the visibility of any ship by limiting its superstructure, particularly the masts and funnels. It would seem that the ideal ship in the past U-boat warfare would be one without masts and funnels, and making use of

anthracite coal and forced draught while in the danger zone. Such a vessel would be invisible to the lurking U-boat even a few miles away, and it is quite conceivable that the U-boat would have to come across the inconspicuous steamers more or less through accident.

The submarine freighter idea has repeatedly come up in considering ways and means of combating the U-boat, and beyond doubt, despite some mechanical obstacles, this type of transport would have proved most efficacious. In truth, the British were employing submerged barges which were towed by small oceangoing tugs, with excellent results.



The *Mauretania*

Showing one type of camouflage that was used to deceive the deadly U-boat.

Fooling the U-boat commander was accomplished by all manner of weird designs. One scheme was to confuse the U-boat's range finder by scrolls and curves in bright colors. A range finder functions best when trained on an object presenting a solid mass, and the disconcerting effect of a nightmare of color and shapes can be imagined by even the lay mind. Certain color schemes tend to give the ship a shortened appearance, while others cause a funnel to disappear so that the identity of the vessel is hidden. In still other instances, a vessel is painted so that a destroyer or U-boat appears to be running alongside her.

Then there is the matter of determining a vessel's speed. In order to aim a torpedo the U-boat commander had to know the approximate speed of his victim and its direction of travel, so that he could aim his torpedo some distance ahead and cause it to arrive at a predetermined point at the same time as the target. Fake bow waves gave the slow moving freighter the earmarks of an ocean greyhound.

Captain Fritz of the U-368, through the "eye" of his slippery craft, estimated the speed of —— to be about eighteen knots because of the high bow wave; whereas the tub might be ploughing along at twelve knots. The result was that his torpedo missed.

Marine camouflage depended entirely on keeping the U-boats beneath the waves. Just as long as the allied submarine chasers and torpedo boat destroyers roamed the sea in large numbers and as long as the merchantmen were armed the U-boat had to seek the shelter of the waves and shoot at its intended victim by the aim of its periscope. And it was far easier to fool the periscope than the human eye at any stage of the campaign.

THE ARMY JUNKMAN

How Every Scrap of Material Was Conserved, to Be Used Over and Over Again

WHAT became of all the metal that the enemy shot at our soldiers? What was the ultimate destination of worn out army shoes and uniforms, of broken down trucks and guns, of old barbed wire and packing cases, of the thousands and thousands of used and worn out and rejected things that abounded on the battlefield and behind the lines? Ask the salvage engineer, if you want an answer to these questions; and he will tell you that it all went back to some useful end, that nothing—literally nothing—was wasted in the well conducted military establishment.

SHOES AND GARMENTS

For instance, the shoe department was one of the most important, and shoes and boots were brought in by thousands of pairs. They were first washed and disinfected, sorted, and then given out to be repaired, inspected and packed for shipment again. The production in this branch was about 3,500 pairs per day. The total value of the output of this department of the American Army salvage for one month was $449,599. About 80 per cent of all shoes received were repaired. At one time this branch employed two officers, seven non-commissioned officers, 114 enlisted men, 280 male and 249 female civilians.

The American salvage depot in France had seven operating departments—laundry, clothing, shoes, rubber goods, harness and leather equipment, canvas and webbing, and metals. The laundry alone employed 206 workers, over half of whom were civilians. All sorts of new devices in machinery were used, save hand labor for washing, rinsing and drying; and more than 75,000 pieces were turned out per day. The clothing was probably the most important department. Its production was limited almost entirely to breeches and blouses, underwear, bed sacks and blankets. The daily output was 10,000 woolen breeches or blouses, 25,000 of underwear or bed sacks and 500 blankets. After coming from the laundry the garments were examined and marked for repair, or if not reparable they were cut up for patches. The patches necessary for the reparable garments were cut entirely from the irreparable ones (15 per cent of the total), and then sent out to the various branches for the actual sewing, after which they were classified either for reissue to the troops in active service or for depot troops or labor battalions. About 1,600 women were employed in this branch, and 75 men. The value of the production for a month was $2,040,831, while the operating costs came to the relatively insignificant total of $93,432.

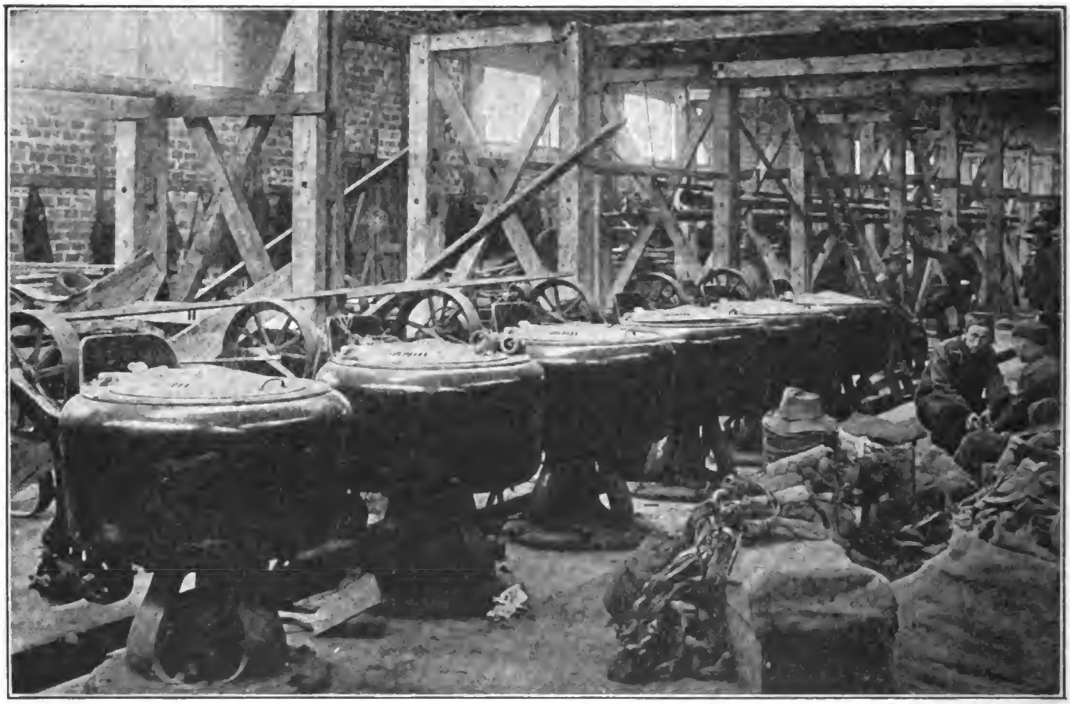
Not a scrap of anything was wasted. Hospital slippers were made from old campaign hats that had been discarded. The question has often been asked as to what became of these hats. In fact they were of an excellent quality of felt, and no matter how old and worn they were, the felt was utilized in the soles of the slippers. The uppers were made from old woolen garments thrown aside as quite irreparable. Overseas caps were another specialty made from old uniforms unfit for repair, and brassards were manufactured by the thousands for the various army services. Old garments were dyed green and marked "P. W." to be used by the German prisoners of war. The old trench shoes that had already been mended and were beyond repair, were cut up into shoestrings. No matter how worn the shoes were, there was always a piece of leather left in the uppers large enough to make several pairs of strings.

RUBBER GOODS

The rubber goods branch also showed remarkable figures for saving. It handled pri-

marily rubber boots and arctics, "slickers," ponchos and shelter halves; it produced about 3,000 garments and 850 pairs of boot per day. The great feature of the department was the new vulcanizing machine which proved most effective in the method of patching. There were employed here 341 persons, principally women. The harness department repaired all the old pieces of harness brought in from the battlefields; after being sorted out, the French harness was returned to the French Army and the British harness to the British Army. The chief items were complete sets of harness, of which about 1,000 were turned out weekly, and saddles, representing about 700 weekly. Some 150 women and 50 men were employed in this work, and the value of the monthly production was $215,453. In the canvas department were handled leggings, haversacks, canteen covers, cartridge belts, medical packs, waist belts and other small equipment articles, and it turned out daily 5,000 canvas articles and about one carload of burlap sacks. Its production in a month came to about $222,878.

The total output for the month of August, 1918, was over three million dollars ($3,246,588), while the cost of production was $315,013; the percentage of cost as compared to the value of output was 10¼ per cent. The actual salvaging operations of the depots started in January, 1918, with five officers, six enlisted men and six civilian employees, while at the end about 10,000 persons were employed. The results show that the plant not only saved a large volume of transport, but over $100,000 per day; and while the coming of peace curtailed the operations of the plant in all metal lines, there was little occasion for many months thereafter for it to abridge its other activities.



© Committee on Public Information.

The Salvage of War Material

Washers and extractors at work cleaning discarded clothing of the American soldiers in France.

RECOVERED METALS

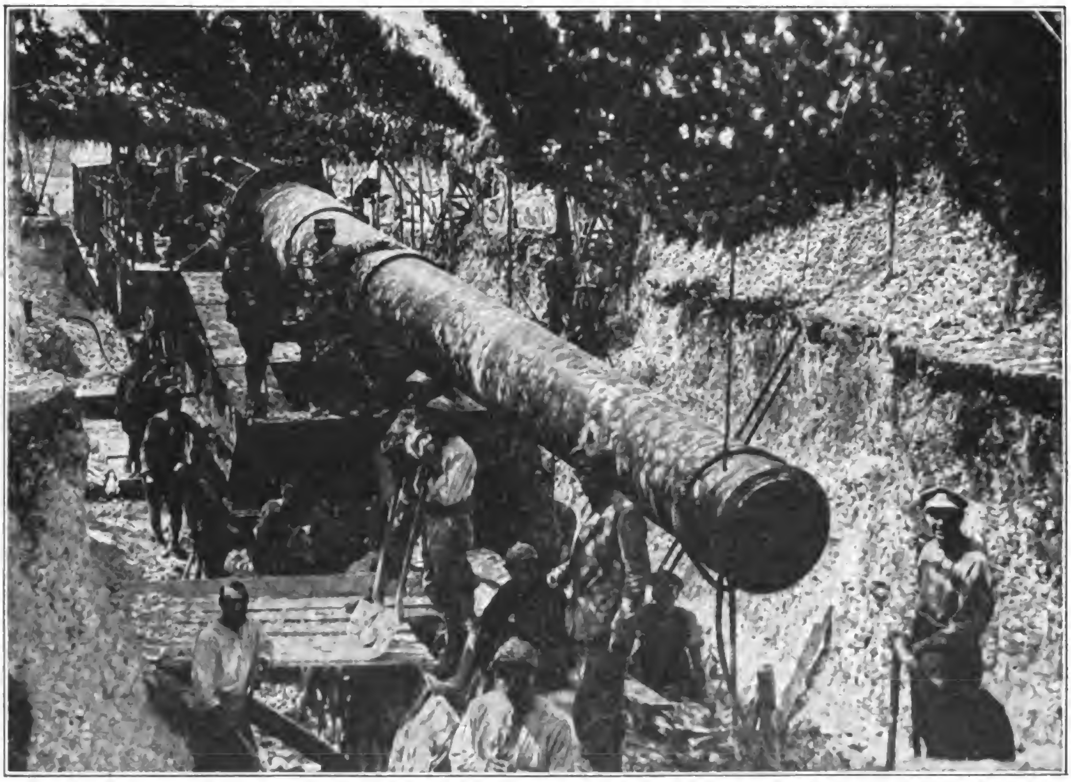
A good deal has been said about the recovery of used metals from the battlefields of France and their re-use; but that the magnitude of this business has been realized is doubtful. It was actually carried out on such a large scale

that there was not room or time or labor enough for it in France, and much of the salvaged stuff had to be shipped to England for re-working.

The headquarters for this work was in Swansea, Wales. There are located here two large firms which have always carried on a notable business in the salvage of warships and cargo-carrying vessels. During the war their activities were extended, under governmental auspices, to the battle waste received from the continent. Formerly, under an agreement between the two governments, the French engineering service undertook the heavy task of collecting the salable scrap from the battlefields on the Western front and working it over into iron and steel bars. But, as suggested, the accumulation of material was so heavy as to necessitate the transfer of much of this work to Britain.

One reason for selecting Swansea as the base for this service was that within twenty miles of the city are found 80 per cent of the tin and terne mills of the United Kingdom, affording a market for the salvaged metal.

The entire industry was under government control. Although half the tin-plate mills in the district were closed on account of government restrictions, a certain amount of tin plate was required by the Ministry of Munitions; so licenses were granted to manufacturers of this article for the purchase of raw materials and especially scrap iron. The reclaimed steel bars not thus used in the making of tin plate were shipped to other parts of the country, where they were rolled into sheet form for use in the manufacture of trench shelters.



Courtesy of Scientific American.

A Large Camouflaged Railway Mount Gun

MACHINE REPAIRS

More closely connected with the actual field operations of the Army were the depots in which condemned machines of every sort—guns, trucks, rifles, engines, airplanes, every-

thing under the sun that contains metal parts —were dissected in search of the last part that can be returned to service in a fresh assembly. An automobile ambulance which was completely beyond repair so far as its top and ignition were concerned might yield a perfectly good radiator and carburetor; the airplane that did not show some usable spars or linen was badly smashed indeed; and it even paid to take apart useless rifles and revolvers and gas masks in the search for something that had not outlived its usefulness. As may be imagined, a good many complete assemblages were put together right in this depot out of the parts salvaged from a dozen, more or less, worn out samples of the same thing; and then there was always a surplus of certain parts which could only be sent to the nearest repair shop for the service in question. Thus, the week's operations would probably result in more front axles and front wheels in good order than rear ones; and since the smallest number was the controlling one, it was necessary to return the surplus of front trucks to the general stock, or to draw upon that stock for the parts of which there was a deficit. In any event, whatever the particular route back to service, it might be assumed with utter surety that nothing that could be used again would escape ultimate employment in some capacity. That is what the army junk shop was for.

THE GYROSCOPE IN THE WAR

The thing which we ordinarily think of when the word "gyroscope" comes up is a heavy, flat wheel rotating at high speed. The important fact with reference to such a wheel is that it resists with great force any effort to alter its plane of rotation, coming back with persistence to a position parallel to its original one.

This peculiar power of the gyro—a power almost uncanny when met for the first time—is so great that the unwillingness of the instrument to change its position is communicated to a ship or an airplane or a torpedo in which the gyro is mounted; and the carrier thus acquires a steadiness which it could not otherwise have. A vessel which would pitch and roll and yaw most violently without a gyro will, after the stabilizer has been installed, ride on an even keel save for the slightest gentle roll. So strong is the tendency of the gyro to maintain its plane that, rigidly attached to the vessel, it is able to hold the vast weight of the latter steady.

The heavier the gyroscope, the greater the force necessary to displace it; and the faster it rotates the greater that force. The big battleships have a stabilizer weighing thirty tons—just a huge fly-wheel of that mass, rotating with great rapidity. Smaller craft have smaller stabilizers.

Another function of the gyroscope depends upon a rather different utilization of its curious power. Here, instead of attaching it rigidly to its carrier, it is suspended freely in a universal mounting, so that it shall be free to swing in all directions. The gyro is fixed in space and the ship is not, so the gyro moves with reference to the ship. And by observing its movement we may learn several things that we want very badly to know.

For one thing, in gun-pointing as in navigation, it is frequently necessary to know the true horizontal plane. This is ordinarily located by reference to the horizon. But at night, in bad weather or in the smoke of battle, the horizon is often invisible and we need an artificial horizon. A bucket of water would do if we could wait for it to settle into rest in a horizontal surface; the same objection applies to a spirit level or a plumb line. But the gyroscope, used as motive power to operate a small plane table, does admirably.

Then there is the gyroscopic compass, developed by an American, Sperry. The magnetic compass is unreliable in the extreme. It is seriously affected by the presence of large masses of metal, which are bound to be on board a warship; and it has its natural deviation, which is different for all times and all places. The gyroscope, on the other hand, can be made to tell us the true north at all times, under all circumstances, and in all parts of the world. In the great navies the gyro-compass has completely superseded the old magnetic compass which was such a wonder in its day.

Painting by Frank E. Schoonover

A Two-Man American 'Plane in France

PART V. THE SANITARY ENGINEER

MAKING THE ARMY FIT

How, as a Result of Tests Developed During the War, the Examiner Can Tell Where a Man's Abilities Lie

IT is necessary that the soldiers of an army be, as a whole, constantly in first class physical condition; but this is not sufficient. If you make ditch-diggers out of the men who should be driving motor trucks, and set to driving motor trucks all those who would be first class material for staff officers, and fill the list of generals and aides from those who are qualified only to dig ditches, your army may be physically in the most perfect trim, but it will not get far in the conduct of the war. It is necessary for every man to be given the work for which he is best fitted before the army can really be considered fit; and this means that, first of all, it must be determined for what work he *is* best fitted. In some cases this is obvious from the previous military or civil record; but the vast majority of men have never found the thing they can best do. For this majority, a thorough-going scheme of classification according to temperament and abilities is necessary, and it must be conducted by a specially qualified medical examiner.

To be sure, for several years there has been a tendency on the part of big business men to make a feeble effort to learn something of the mental qualifications of applicants for employment. The methods used have, however, been decidedly random, altogether empirical, lacking in any semblance of uniformity or general acceptance, and uncertain in their results. They had, in fact, contributed rather to making the psychologist a laughing stock and excluding him from the ranks of the exact scientists, than to any general belief in his procedure and his findings.

In spite of this state of affairs, the Army authorities in charge of America's great draft sifting had the courage to believe that these methods were fundamentally sound, and that all they lacked to bring them to a basis of regular practice was opportunity for wide application and development. It is quite plain that if the refusal of the first automobile or the first trolley car to run smoothly were to be accepted as final dictum against any further attacks upon the problems of electric and automotive transportation, the achievements of the past twenty-five years in these directions would have been out of the question. The American medical service, fortunately, possessed sufficient imagination to realize that the psychological test, in 1917, occupied a position wholly analogous, let us say, to that of the automobile in 1898—in other words, it was not working, but it was certain that it could be made eventually to work. So the medical service seized time by the forelock, compressed the normal development of twenty years into a few months, and thereby placed to its credit one of the largest permanent achievements of the war. Indeed, in summarizing the scientific advances made during the conflict, the *Scientific American* placed this one well to the fore, saying:

"Perhaps in no field of science has the war stimulated such sudden and such notable advances as in that of the psychologist. He has had unprecedented opportunity to observe the behavior of men under conditions of stress; and he has been called on to make tests, and perforce to devise methods and machinery of test, on a scale never before contemplatd. He has proved his technique to himself and to others, so that he now stands on a level of achievement and recognition which he could not have attained in years of normal activity."

WHERE PSYCHOLOGY SCORES

The actual tests employed to sift out the various grades of mentality are almost ridiculously simple—so much so that the soldiers to whom the tests are applied refer to them as the "nut exams." Nevertheless, no catalogue of the scientific part of the war would be complete without an account of these methods. It is plain that the first item on the program is a wholesale combing for the men of low mentality. This is accomplished by an intelligence test which can be given to a hundred men at a time. The rejects are turned over to the psychiatrist for expert attention. Those who are not actual malingerers are either imbeciles or of such low intelligence that they may only be recommended for certain kinds of simple manual labor under close supervision. Then it is necessary to weed out the kind of man who is brought repeatedly before his company commander for discipline, or who, during illness or at some other time, will reveal constitutional nervous weakness. These are the men who will fall out or run amuck on the firing line.

THE "NUT EXAMINATION"

The first establishment to perform this sort of classification was that organized at Camp Lee, Va., in the fall of 1917, under the personal supervision of Surgeon General Gorgas. Picture a large room, with 75 or 100 khaki-clad soldiers squatting on the floor, Turkish fashion, writing boards and printed blanks on their knees. The examiner stands in front with a stop watch in hand.

"Attention!" he sings out. "Make a mark in the largest square of this row of squares. Go!"

This is one of the simplest exercises, which can be done by every recruit who is competent to understand and carry out directions. Similar exercises in this faculty follow, each more difficult, until the last may be something like this:

"Cross out the letter just before *C* and draw a circle around the second letter before the third *K*. Go!" Or perhaps it may be:

"Make a circle in the part of the square which is in the triangle but not in the big circle, and put a cross in the space that is in the circle and the square but not in the triangle. Go!"

The next test is for memory span. The examiner reads aloud a set of three figures, with the men at attention, pencils lifted from paper. They are then given a few seconds to write down the set. The numbers increase in length until the last one contains twelve digits. Many have given up trying by this time, and only the memory wizards get the last set right.

The test which stumps the greatest number of recruits is that of completing a numerical series. Thus, given the series 3, 7, 11, 15, it is easy enough to supply 19 as the next term; but in the series 31, 28, 30, 27, what number should follow 27 to preserve the law of formation indicated by the part of the series already given? This law tells us to subtract 3 and add 2, alternately; so the next term is 29. But there is a little trick about this that puzzles the average recruit. For before one can apply the law of formation one must discover what it is; and this requires power to sense relations in the abstract. The man who can do this will carry the same power over into realities. He will be able to transfer the basic principles of trench-digging from the environment in which he has been taught them, and apply them to any kind of landscape that presents itself.

Other tests follow. Sentences whose words are not in proper order are given, and the men are asked to indicate whether these, if properly arranged, would make a true or false statement. Arithmetical problems are given which involve little computation but which tax ingenuity. One of several given words must be chosen which will so complete a given sentence that its statement becomes true. From a given group, a pair of words (like good, bad) must be chosen which bear the same relation (of oppositeness, etc.) as a given pair (like white, black). The whole thing is over in fifty minutes, the papers gathered and taken to the grading room, and the soldiers returned to their normal camp routine—with no weird questions or emotional shocks of any kind. The possible variation of questions is so great that no amount of cramming will materially increase a man's grade.

In another room those who cannot read and write and those who failed in the group in-

telligence test take the mechanical skill test. This consists in putting together dissembled pieces of mechanism—a bell, a monkey-wrench, etc. If a recruit passes neither test, it is then time to subject him to the recognized procedure of the laboratory psychologist, which definitely fixes his mental age and gives a line upon his capabilities. Obviously such a man may not be trusted with any responsible task such as sentry duty or the charge of a squad; but he may be able to peel potatoes with the best of them. The psychologist at the end of a two-hours' quiz can make definite recommendations.

The general tests are not finely discriminatory, for the effort is not being made to sort out the aviator type from the artillerist, or the signal corps officer from the sharpshooter. The men are merely card-indexed according to their mental furnishings. This culls out in speedy fashion the men of low attainments, and it is of immense value as a basis for promotion, or in the assignment of men to tasks calling for more than average intelligence or mental quickness. The idea is not to weed out the imbeciles, for that is easy to do; it is to classify the normal men. The fact that over 75 per cent of the judgments, based on the test records, coincide with those of the officers who know the men best from everyday experience, and that in many specific instances, all the men chosen for promotion on the basis of daily achievement have been those of highest test ratings, shows how nearly the mark has been hit in making the thing a practical procedure.

PEACE-TIME APPLICATION

As a single indication of the standing which this technique of test has it is only necessary to state that Columbia University has adopted it for entrance examinations. The old system of examining the prospective student for specific knowledge of the subjects previously studied will not be abandoned altogether; students will be permitted to elect this, or the new method of qualifying for entrance. If they choose the latter, the only actual test which will be applied to them by the University will be the one outlined above. This went into effect in the fall of 1919; and Dean Hawkes of the College sums the matter up about as well as it can be summed when he says: "We expect these tests to show us whether it is worth our while trying to give the man a college education, and whether it is worth his while to have us try."

THE MEDICAL PROPHET

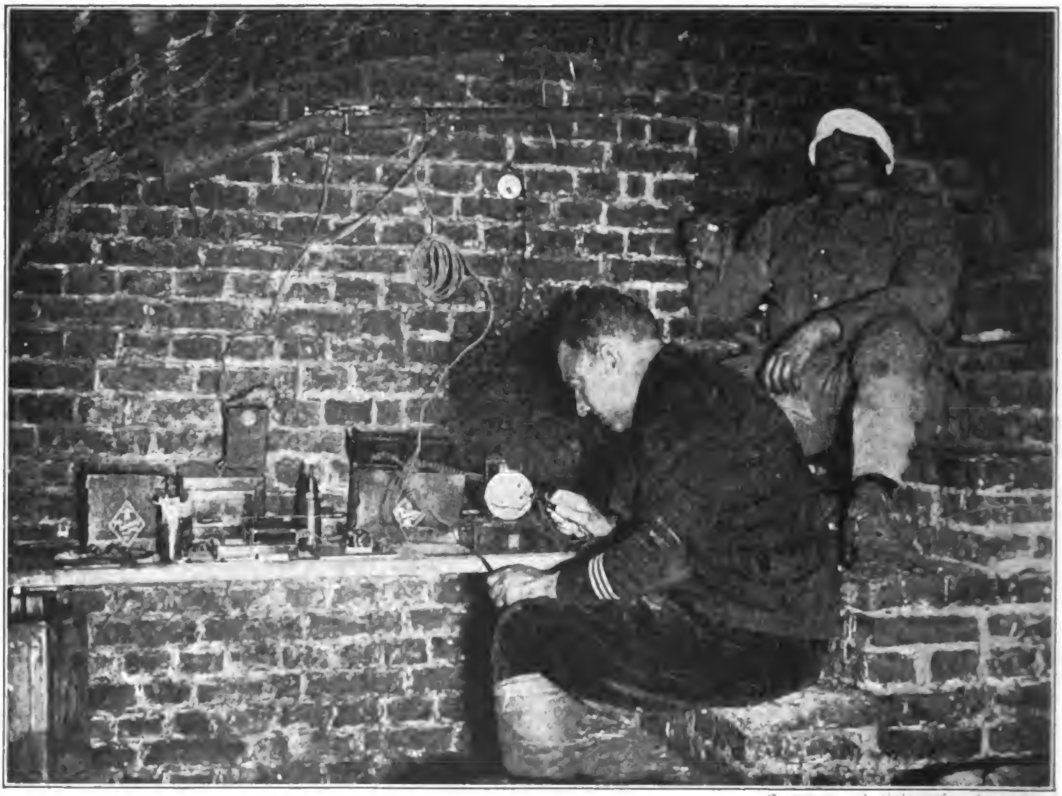
How the French Physician, Miles from the Front, Predicts a Recruit's Behavior When He Gets on the Firing Line

ALTHOUGH the whole plan and technique of intelligence tests for application to all army recruits is a distinctly American development, it really takes its inspiration from previous activities of the French in trying to find whether a man would make a satisfactory aviator, machine gunner, etc. Here the effort was not directed toward general intelligence, but rather toward learning the speed and certainty of the candidate in those reactions which come most into play in the service for which he was seeking to qualify.

From the moment when the course of the war gave the French their first breathing spell, they have shown a peculiar aptitude for this psycho-physiological investigation, as they call it. This formidable term refers to the building up of a series of tests, partly mental and partly physical, by means of which a candidate for aviation or ambulance-driving or any other form of special work is made to reveal his ability to do that work while still far from the scene of action, and without the formality of an actual trial. The tests differ from the general psychological test as suggested, in that they discard all general principles, and determine nothing about the candi-

date except the success which he will enjoy in the actual performance of the special duties for which he seeks to qualify.

In building up these tests, several steps are necessary. First, a careful analysis must be made of the actual motions of arms, feet, hands, etc., which are demanded in the performance of the work under consideration. These must then be translated into terms of psychological impulses and reactions; and finally, instruments must be devised for measuring the speed, certainty and endurance which the candidate displays in the reactions involved.



Courtesy of Scientific American.

Determining a Soldier's Fitness by Electrical Means

The French have worked out a remarkable system of tests for determining the mental and physical characteristics of any soldier, and so fitting him to the task he can best perform. Here is a candidate undergoing one of these electrical tests in a cellar near the front.

HOW FAST A MAN REACTS

The first series of tests developed were those for the aviator. Here the prime requisite was the rapidity with which perception and thought are followed by action. For suppose that an aviation pilot suddenly discovers, for example, a machine gun, which has been concealed from him up to that instant by the topographical features of the ground beneath him; how much time will he consume in the execution of a maneuver for the purpose of avoiding its fire? Or, if a violent wind threatens the destruction of his machine, how many seconds are necessary for him to put into operation the lever which will assure his retreat from the atmospheric danger zone?

The d'Arsonval chronoscope is employed in answering these questions. In its essential features it consists of a clock dial divided into 100 parts, with a single hand. An electric circuit is so connected with the movement of this clock, by means of a steel spring, that while the circuit is broken the mechanism

moves the hand at the constant normal velocity of one complete revolution per second, whereas the instant the circuit is made the spring contracts (under magnetic influence) and pulls the wheels out of gear, halting the hand instantaneously.

To measure the time of reaction of an ordinary stimulus, the observer seats himself before the candidate, holding in his hand a tiny hammer. By striking this hammer sharply against the table he at the same time gives the stimulus to which the candidate is to react, and breaks the circuit by means of an electro-magnetic device connected with the hammer. The candidate holds in his hand a small metallic pincher. Immediately upon perception of the sound, he squeezes this together, thereby making the circuit again. The length of the interval during which the circuit was broken, representing the time of the subject's reaction, is read off from the dial by noting how far the hand moved during that interval—*i. e.,* while the circuit was open.

In entirely similar fashion the time of reaction to impressions of touch is measured; only this time the blow is struck upon the candidate's hand or the back of his head. Likewise the operations of the subject's sense of sight are recorded by the doctor's pressing the hammer gently on the table, the subject stopping the motion of the clock-hand as before, directly he perceives this act.

Application of these tests to a large number of candidates has established auditory and tactile reaction intervals of 0.14 to 0.15 second, and visual interval of 0.19 second, as a first-class performance. Candidates with auditory intervals greater than 0.17 second, tactile intervals greater than 0.2 second, or visual intervals greater than 0.22 second, are rejected as unfitted for aviation service. The slowest reaction intervals yet observed in candidates who are psychologically normal are, respectively, 0.33, 0.39, 0.48 second, for the three varieties of sense reaction, in the order in which they are mentioned above.

TESTING THE CANDIDATE'S EMOTIONS

The preceding data are then supplemented by determining to what extent the candidate's respiration and heart action are affected by his emotions; and also how his vaso-motor tension is modified and what degree of muscular trembling is produced by physical surprise and mental stress. A sort of recording stethoscope is attached to the candidate's chest. This instrument conveys the respiratory vibrations to an inked needle which records them upon a moving sheet of paper. By similar means the cardiac vibrations, the vaso-motor oscillations, and the trembling of the hand when supported only at the wrist, are re-

Courtesy of Scientific American.

Testing a Machine Gunner

The man being tested has a small pencil-shaped object with which he jabs the board at regular intervals with a downward motion until he is completely fatigued. The machine records the speed and the variation of the strokes.

corded. After the candidate has been hitched up to all this apparatus a revolver is unexpectedly shot off close to his ear, or a wet cloth suddenly applied to the back of his neck, and the effects of this treatment on his several functions under observation are read off from the graph.

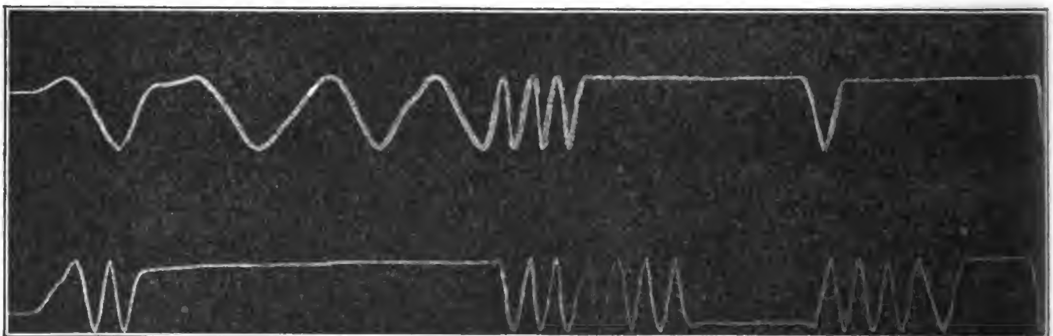
Further interesting tests are designed to measure the degree of local fatigue induced by extensive strain on the hands and arms, and in particular by the long-continued compression of the hands demanded of the aviation pilot. In the instrument employed in testing the en-

durance of the candidate's fingers, his arm and hand are so confined that only the one finger being tested can possibly do any effective work. To that finger is attached, by means of a cord running over a pulley, a scale pan with iron-weights in it. A tooth gear furnished with a brake makes it possible for the candidate to raise this pan by contracting his finger, but prevents the pan from going down again when the finger is relaxed. This is necessary to obviate the fatiguing factor of shock from the descending pan, which could not be intelligently estimated. The candidate works his finger back and forth until it is incapable of further movement, whereupon the total weight of the pan is multiplied by the distance he has lifted it in the aggregate, to obtain an index of fatigue for the finger in question.

In all these tests a standard of comparison was established by application to a number of France's most distinguished military aviators. It will be readily seen that the combination of rapid reaction with nervous imperturbability and physical indefatigability demanded by aerial work is a difficult one; and the standard thus obtained insured against setting too high a minimum for the recruits.

A TEST FOR EVERY CALLING

After the successful application of the psycho-physiological tests for aviators, the principle was rapidly extended to other branches of the service. In connection with the tests for machine-gunners, it is of interest to note the very detailed analysis that was made of the physical and psychological requirements. It was pointed out that "the gunner sits upon the low seat attached to his weapon, body slightly bent, eye at the notch of the sight, hands on the trigger and controls. The process of aiming calls for muscular rigidity, which the scientist translates into terms of 'functional adaptation.' Firing begins by pressure on the trigger, and ceases by release of the trigger. These operations demand what the psychologist knows as 'motor rapidity,' or ability to make action follow stimulus with a minimum delay, and 'absence of motor suggestibility,' or ability to resist the impulse to duplicate the movements which he sees others make, or which are suggested to his mind through some other avenue."



Courtesy of Scientific American.

Motor Suggestivity Curve (below) of a Poor Gunner

Who was trying to repeat the motions recorded above.

These statements, of course, apply verbatim only to a single type of machine gun, the St. Etienne which was in use in the French Army when they were compiled. But in general principle they apply to all subsequent guns. They show clearly that all the actions involved call for motor rapidity, precision in small movements, dissociation of movements (an attempt at rotating the two hands simultaneously in opposite directions, *one* hand alone to be reversed at a word, will help the reader to appreciate what this means), and rapidity of decision.

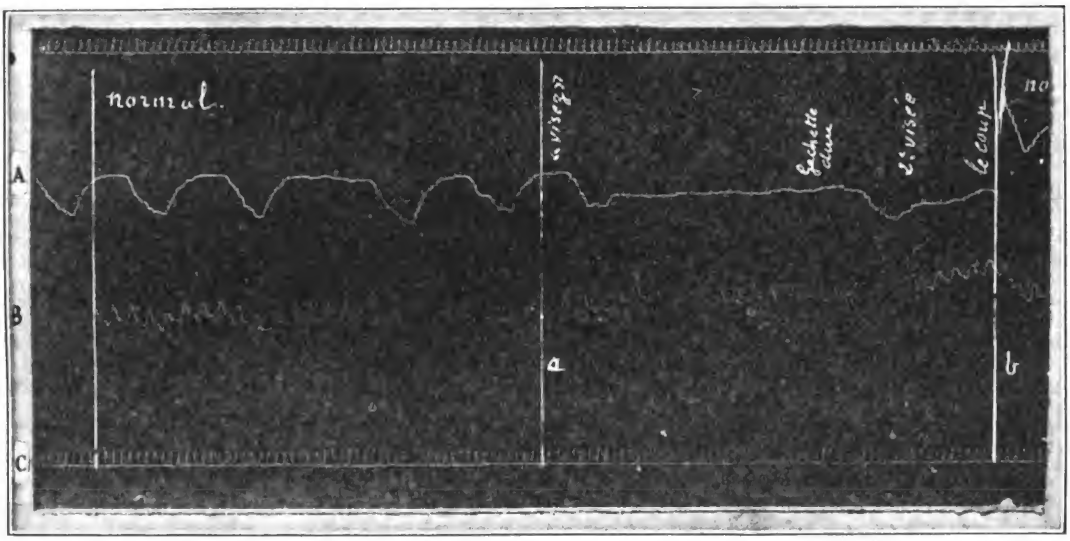
It was found possible, in connection with the test for motor rapidity, which here assumes great importance, to improve slightly upon the chronoscope described above. There was introduced into the circuit an electri-

cally operated tuning fork, giving fifty double vibrations per second, equipped with an interrupter so that, at each oscillatory movement, a current of very brief duration passes into the magnet and checks the dial hand in its rotation. The length of time which the subject consumed in his reaction was then measurable in terms of retardation of the clock hand.

HOW TESTS CHECK WITH FACTS

The figures obtained in the course of the preliminary investigation of this apparatus were very complimentary to the gunners involved. These men, acclimated to war by eighteen months in a sector of great activity, possessed motor speeds far beyond the normal. Thus, out of one squad of 20 men examined, the 13 best gunners showed an average visual reaction interval of .144 second and an average auditory reaction interval of .1157 second. For the seven poorest men the figures were respectively .2142 and .1884 second; the general mean for all 20 was .1686 and .1518 second. Even these general means are well below the classically recognized means of .195 and .15 second, respectively; and the best men throw these norms completely into the shade. Indeed, the findings have been severely attacked on this ground, but without very apparent justification. That the subjects of this test should be far above the average in this matter, to them one of life and death, is hardly surprising.

Be that as it may our psychologist pursues his inquiry to study the rapidity of repetition of a given movement. The movement selected for this test was a light blow upon a copper plate with a small stiletto. Contact between stiletto and plate establishes the circuit and marks upon a recording cylinder each blow given. In this way not only the actual number of blows in an entire interval is recorded, but an index of fatigability is obtained by comparing the rates at which the stiletto fell during the beginning and during the end of the test.



Courtesy of Scientific American.

The Test of a Gunner

How the respiration (above) and the pulse (below) of an excellent gunner respond to the demands of action, which in this case consisted of aiming and firing a gun. The interval from *a* to *b* is that of extreme effort.

An interesting part of the test is that relating to motor suggestibility, in which the standard Binet apparatus is used. Here it is found that the better men reproduce not only the starts and stops of movement communicated by the experimenter, but even the minor variations of speed; while the poorer "coffee-grinders," as mediocre gunners are termed by

the poilu, are distinguished by a sort of motor hallucination, believing that they have felt impulses which were not given at all.

One item which required long thought on the psychologist's part before he could reduce it to its symptoms was that of coolness under fire, or *sang-froid,* as the French call it—cold-blood. He was finally reduced to experimentation. He recorded the variations of pulse and respiration of a subject engaged in a brief act, but one demanding a considerable effort of attention. Firing a carbine is a fair example of such an act, and one which was employed, among others. Respiration and pulse are "taken down" by a recording needle, and the graph obtained permits clear classification. Good subjects adapt their organism spontaneously, either by arresting completely the respiration, or by modifying it noticeably. When a normal respiration would be in their way, in other words, they put it out of the way by breathing in such abnormal fashion as meets the needs of the situation. Their hearts and lungs are never "in their throats."

Again, among the good men, the blood pressure curve maintains itself horizontally before the experiment, or at most slightly and rhythmically undulatory, and shows a prompt rise at the beginning of the test. The ascension increases until the discharge of the gun marks the end of voluntary effort, and then falls progressively. The rapidity of the return to normal again indicates great functional plasticity, this time on the part of the heart. On the other hand, the excitable subjects present curves of great irregularity. Further, among the good men the pulse increases during action, while among the poorer ones it remains fixed or even falls—their organisms are not responsive to the necessities of action; they lack the "pinch-hitting" ability.

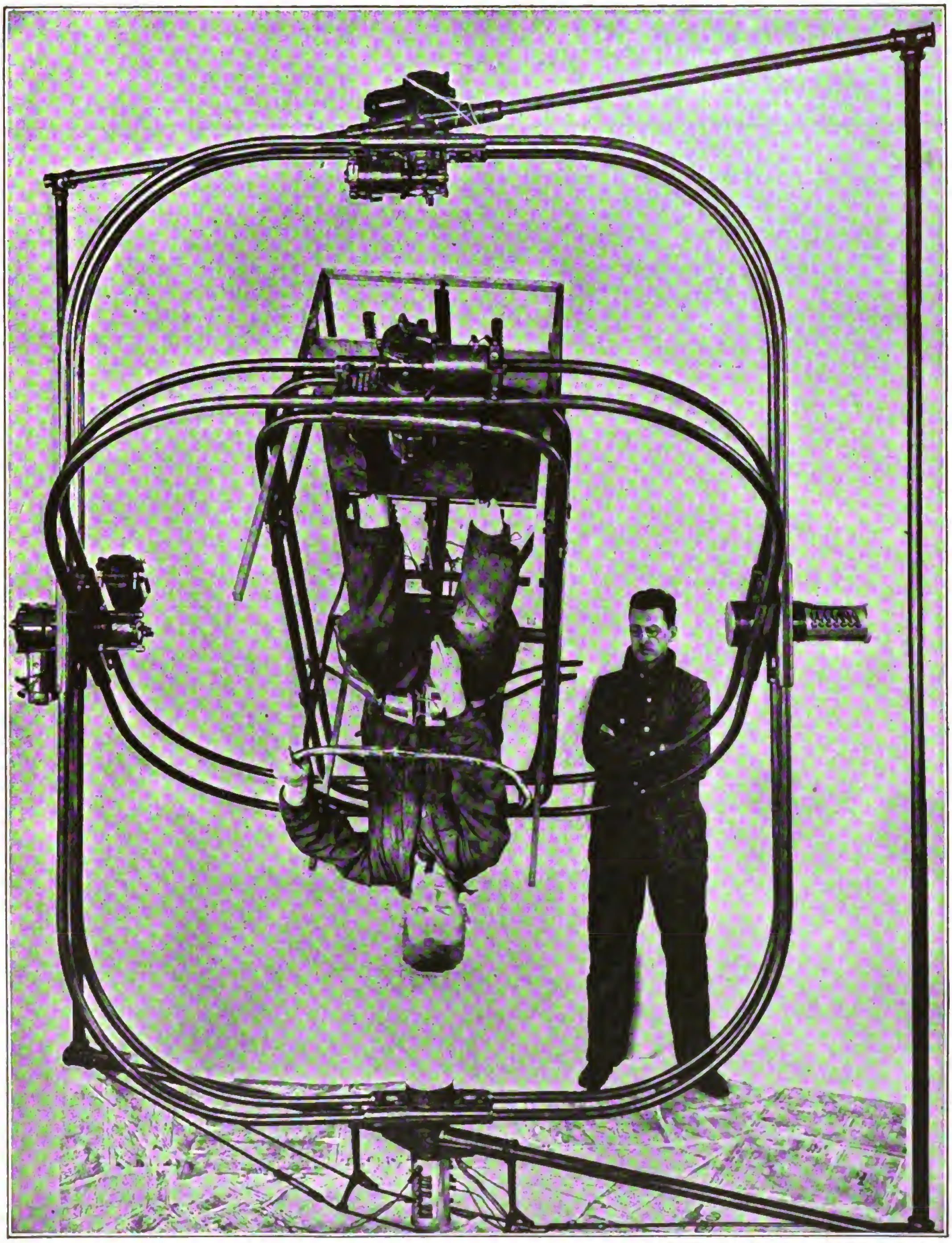
The really extraordinary feature of all this is that every test works. If a group of gunners and feeders is classified according to the testimony of the officers who have observed them in action for a considerable period, and then subjected to this examination, the men of observed ability will pass with high standings, and those of known inability will fall down hard. In every case, the good gunner or the good feeder will be found to possess the traits called for; and the converse statement, that the man possessing those traits will make a good gunner or feeder, will therefore be regarded as established within a reasonable degree of probability.

SAFEGUARDING THE SERVICE

Ingenious Mechanical Devices Invented by American Physicians that Combine Test, Instruction, and Detection of Fraud

SATISFACTORY as they are in practice, the methods of pre-testing developed before the American entry into the war are on their face empirical. When the United States enlisted, our surgeons made a very special endeavor to improve upon the known methods, particularly with reference to aviation tests and the detection of malingerers. It was felt that in view of our very ambitious aerial program we could not afford to be satisfied with any process of selecting the men which did not rest upon a thoroughly solid foundation of theory. By careful investigation it was found that the fundamental reasons for good and bad flying were to be localized in the canals of the ear. These are three in number, semi-circular in shape, each lying in one of the three fundamental planes of space. They are filled with a fluid, and it is the motions induced in this fluid when we change our position which give us our sense of equilibrium and enable us to maintain balance.

We are dizzy after being spun about, because after the body stops the fluid in the semicircular canals, on account of its momentum and its freedom to move independently, goes on spinning for a time. Until it is at rest again the head suffers from the sensation of whirling. We are thrown out of balance by a sharp change in position for the same reason.



Courtesy of Naval Consulting Board.

The Ruggles Orientator

This apparatus was used to test applicants for the aviation service. It can reproduce every motion of the airplane, with the unimportant exception of actual forward acceleration.

And it is found that the aviator who does not behave normally *after a proper season of training* is the one whose semi-circular canals are abnormal and therefore not responsive to training. So now we test the prospective aviator by reproducing all the things which can happen to him in the course of his flying, and noting the results upon his semi-circular canals, as betrayed by his behavior.

TEST COMBINED WITH EDUCATION

The apparatus for this is a highly ingenious piece of mechanism known as the Ruggles orientator. This is a little car much the same in general get-up as the cockpit of an airplane. It is suspended upon three mutually perpendicular axes in such a way that it can be made rigid along any one or two of them, and rotated about the rest; or it can be rotated about all three simultaneously. It is obvious that any change of position, any maneuver whatever, that can be produced in the airplane, can be produced here, with the unimportant exception of actual forward progression. In one model for the testing of experienced flyers the controls are in the car itself; in another, for use on the novice, they are elsewhere, where they can be operated by the examiner. Strapped in this machine the man under observation can execute or have executed for him any evolution, such as the loop, spiral, etc., at any desired rate of speed for any number of turns. He can thus acquire in absolute safety a tolerance for the disturbing effects of the vertigo induced by these evolutions instead of acquiring this tolerance and knowledge by actual flying with its frequent crashes and loss of life. And if he fails to make this adjustment within a reasonable time, that is the necessary and sufficient proof that he will never make it—that aviation is not his game.

The orientator is thus at the same time a testing apparatus for weeding out the absolutely unfit, and a means of instruction for those who are fit. Its installation in the ground and flying schools will without doubt save many lives; and on the whole, it may be accepted as the culmination of the efforts of that branch of the medical service which is engaged in the prevention of the assignment of men to work for which they are unfit or not yet fitted.

THE MALINGERER

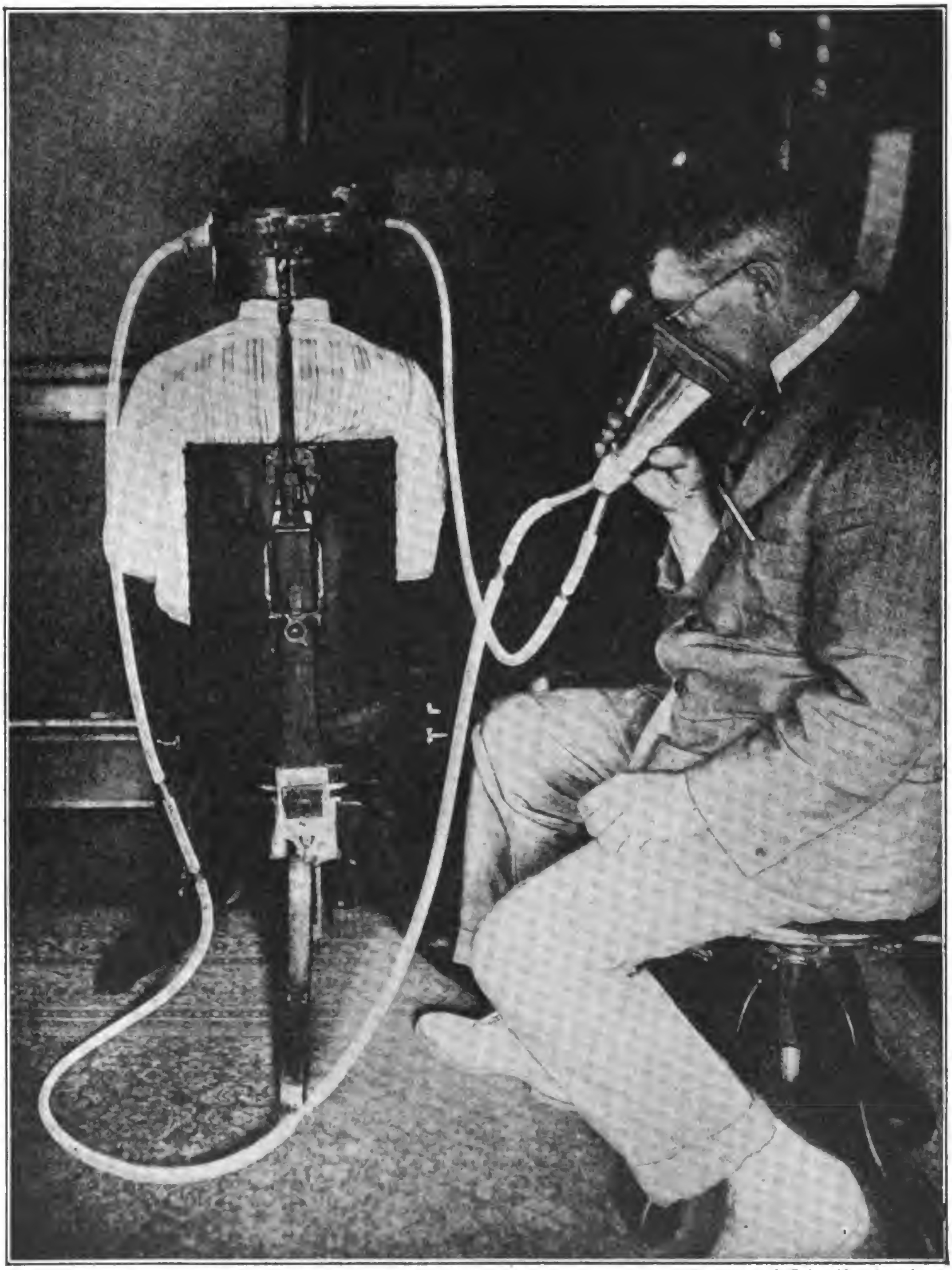
In addition to the man who wants a place that he cannot fill, we have always with us the man who lies to the doctor, or otherwise attempts to deceive him.

Exigencies of war developed a good many procedures, and a few pieces of apparatus, which will be of permanent value as tending to unveil such petty deceptions. In examining men for the army, it is of course necessary to arrive at correct judgments—far more so than in civil practice, where the patient is the only victim of his own misstatements. There are of course various more or less well-known ways of tripping the malingerer; but the war has added new ones. Perhaps as interesting an example as could be adduced is the invention of a New England Draft-Board physician for finding out whether a man is really as deaf as he says he is. It should be emphasized that this is a common claim—perhaps the most common one put forward by those seeking to evade service. The would-be malingerer realizes that the doctor may often look into the eye and determine for himself what it sees and what it does not, or that by tests to which he alone knows the correct answer he can trip up the false claim of defective vision; he realizes that physical examination will often defeat the effort to get by with a muscular infirmity that does not exist; but it always seems to him that in the matter of what he hears, the examining physician has no recourse but to take his word. And this is largely correct—or would be but for the means of detection which we are going to describe.

It was an observation of the ancients that the greater pain obscures the less and that, in a general way, strong sensations prevent the appreciation of weaker ones. In precise terms, stimuli that are similar in all their properties except intensity are not dissociated by the mind, only the stimulus of greater intensity being so registered that we are conscious of it. This law was utilized in the detection of false claims of deafness in one ear.

HOW WE HEAR

When a sound reaches each ear with the same intensity we are conscious of hearing it in



Courtesy of Scientific American.

Testing a Suspected Malingerer with the Voice

It will be noted from the photograph that the tubes to the ears of the person who is being examined are of different lengths, so that the voice necessarily carries better to one ear than the other; an essential feature of this test.

both. When it reaches each ear with different intensities we are conscious of hearing it only in the ear where intensity is the greater. Thus tuning forks vibrating with the same pitch and loudness one inch from each ear are heard in both ears; but if the fork at the left ear is removed to a point three inches away this sound is lost and only the fork remaining at the right ear is heard. But if now, the latter is put six inches back, it will no longer be heard, while the left one, formerly not sensed, will become audible.

Tests which depend upon the suspected malingerer not knowing in which ear he hears the test sounds are an insult to his intelligence; the patient can successfully concentrate his attention on his good ear and suppress what he hears in his supposedly bad ear. The most we could here expect would be to trick a patient who was not very sharp; and even then we could merely ascertain that he was not totally deaf in his "bad" ear—we could never determine the extent of hearing he had in that ear. So a procedure was worked out where the patient knows which ear does the hearing, but where he is betrayed by his ignorance of which one ought to do it if his claims were correct.

The sound is brought to the patient's ears through rubber tubes. It is necessary to eliminate the possibility of bone conduction, since the vibration in the tubes can often be felt with the hand. So instead of being attached to the patient's head with lugs, the tube-ends terminate in a curved arm attached to the chair-top; and after the patient is seated, these ends are brought to within an inch of his either ear, without any contact between him and the apparatus.

The sound may be produced in various ways. The inventor of the test has used tuning forks, and a megaphone manufactured from an old ether cone. In the former case, the desired length of tube is got by a metal clip joining the two tubes, which at the same time makes it possible to use a single fork; and the parts of the tubes beyond the clip simply do not figure in the test. In the vocal test, where the cone has actually to be at the physical end of both tubes, metal couplings and auxiliary tube-lengths are used. In either event, the mechanical details are sufficiently obvious.

If the patient has two good ears, when the tubes are of the same length he will hear the sound in both ears. There will be a neutral zone of two or three inches around this point in which the same result will be obtained. But the minute either tube becomes appreciably longer than the other, audibility will be confined to the ear that pertains to the shorter tube-segment.

APPLYING THE TEST

If the patient really has a bad ear, each ear will have been tested separately; it will be found, say, that he hears in his good ear up to 20 feet, and in his bad ear up to 3 feet. With both tubes in use at the same time, he will hear the sound in his good ear whenever the length of the tube leading to it is less than 20 feet while that of the tube leading to the bad ear is greater than 3 feet. The minute we get his bad ear within 3 feet of the sound while the good ear is 20 feet or more away, he will hear in the bad ear. And proceeding from this point to move the sound nearer to both ears at once, if it is 6 inches from the bad ear and 18 feet from the good one, the intensity *of audition* will be greater in the bad ear. The patient will then hear in the bad ear, and the good one will register no sound—although if the bad ear were closed, he would hear in the good one.

Suppose now that a malingerer has claimed deafness in his left ear. If he claims partial deafness he will be tripped up in short order by sounds whose intensities and distances are not known to him; so realizing this, he claims total deafness in the ear in question. He must then go into the test with the determination to say no whenever he hears a sound in his left ear; otherwise he will presently admit hearing something which he should not hear. Very well; in the case outlined in the preceding paragraph, he hears the sound in his bad ear, and denies hearing it at all. Then he is caught; for if his left ear were deaf he would hear it in his right, and if his left ear were not deaf he would hear it in his left.

Of course the distances in the above suppositious case will be greatly modified according to the facts of each case. But in every case there will be a region where the malingerer hears the sound in his "bad" ear, so that he must deny hearing it at all, yet in which he

could hear it with one ear or the other if his claims were true. Thus, suppose he really hears at 30 feet in his left ear and at 20 feet in his right, and has claimed deafness in his right ear. When the tubes are so adjusted that the source of sound is 10 feet from his left ear and 6 feet from his right, he will deny hearing at all!

In every case the range of the good ear can be determined in advance by separate tests of the two ears; and in every case the patient, by his negative answer, unconsciously gives exact information as to just what degree of hearing he has in his alleged bad ear. For as the sound-source retreats from the good ear and approaches the bad one, he marks the point at which he begins to hear it in his bad ear by changing his claim from "hear" to "do not hear." There seems no escape for the unfortunate victim of this ingenious device—except that of telling the truth about his hearing to begin with.

THE SURGEON AT SCHOOL

How Accepted Practice in the Treatment of Wounds Had to Be Thrown Overboard and a Fresh Start Made

THE surgeon, as well as those more intimately concerned with the actual conduct of hostilities, must keep up with the facts; he must be prepared to scrap old procedures and even old accepted laws, when the march of events so demands. Indeed, he is more at the mercy of circumstances than anybody else who has to do with the war. For where the man who designs the weapons and the man who uses them are able largely to influence the nature of the problems that come to them, the surgeon's work is imposed upon him altogether from outside. He must deal as best he can with the wounds that arise from the current methods of giving battle, and nothing he can do will modify in the least the problems that are presented to him.

Now the layman could hardly be expected to realize, without having had it pointed out to him, that the war of 1914-18 involved a radical turning over of surgical practice. To understand why this should have been so we must turn back to the Russo-Japanese War, the last first-class conflict before the World War. In this war, the vast majority of the casualties on both sides were produced by rifle bullets, and incidentally of course by a direct hit. Now the modern rifle bullet causes a mortal injury when it hits a major organ or a large blood vessel; but otherwise its effects are extraordinarily mild. In the first place, it has such a high velocity that in at least seventy per cent. of cases it does not remain in the victim's body at all, but simply perforates a neat little hole through him and goes on its way rejoicing. In the second place, it is subject to such heat and such mechanical action as it passes down the rifled barrel that it is practically sterilized before it leaves the gun, and remains sterile through its flight. So it leaves a course with clean-cut edges not favorable to infection; and in particular, it does not itself introduce the elements of infection.

RIFLE WOUNDS AND SHELL WOUNDS

Treatment of such wounds as are made by this rifle bullet is absurdly simple. They are sterile; all we need do then is to see that they remain sterile, and wait for nature to effect a cure. The dressing attends to the first of these demands, and time and patience attend to the others. These principles had found their application in the individual first-aid packet which, applied by the wounded man or by a comrade, was to prevent practically aseptic wounds from being contaminated later by the clothing, dirt, handling, or any other source of infection. The French surgeon, Major Matignon, who followed the war operations from the Japanese side, reports that Japanese soldiers, struck by Russian 6.5 mm. bullets, would often continue to run after

being hit and that numerous wounded, after weeks of different kinds of transportation, arrived in Japan cured without surgical attention.

The war with Germany, however, was not fought out with the rifle as was the Asiatic conflict of ten years earlier. Where at the battle of Liao Yang, 97.9 per cent. of the wounded men in a certain Japanese division were hit by rifle bullets and only the remaining 2.1 per cent. by shell fragments or shrapnel, it was the general experience of the Allied and Teutonic forces that about 80 per cent. of the wounds incurred were due to shell fragments and only 20 per cent. to rifle or—what amounts to the same thing so far as the surgeon is concerned—machine-gun bullets. And this completely overthrew the surgery of war, as it was supposed to have been established in 1904-05.

For the shell wound cannot by any possibility be a sterile one. The shell fragment, with irregular edges, arriving at low velocity, penetrates the organism with a twist, tears the tissues, and carries to the bottom of the wound pieces of clothing or leather, with particles of earth and wood. It rarely goes clear through, remaining as a source of infection in the lacerated and stupefied tissues, which are ready then to serve as a medium of microbe culture.

Previously, with a sterile wound, it had been possible to lay down the law that the fate of a wounded man depended upon the first dressing. For if this were well and promptly applied, the agents of infection would have been excluded from the sterile wound, and this would accordingly remain sterile. And when a wound is and remains sterile, it heals—heals almost without any aid, and in a marvelously brief time. For the best surgeon of them all is nature. In the absence of infection the wound starts to heal itself at once and goes right ahead with the job until it is finished. This is what is meant by that term, so much used and misused, and about which so much mystery has been thrown—healing by first intention. It is the first intention of the wound to go ahead and heal, and this it will do unless something happens to interfere. That something is infection.

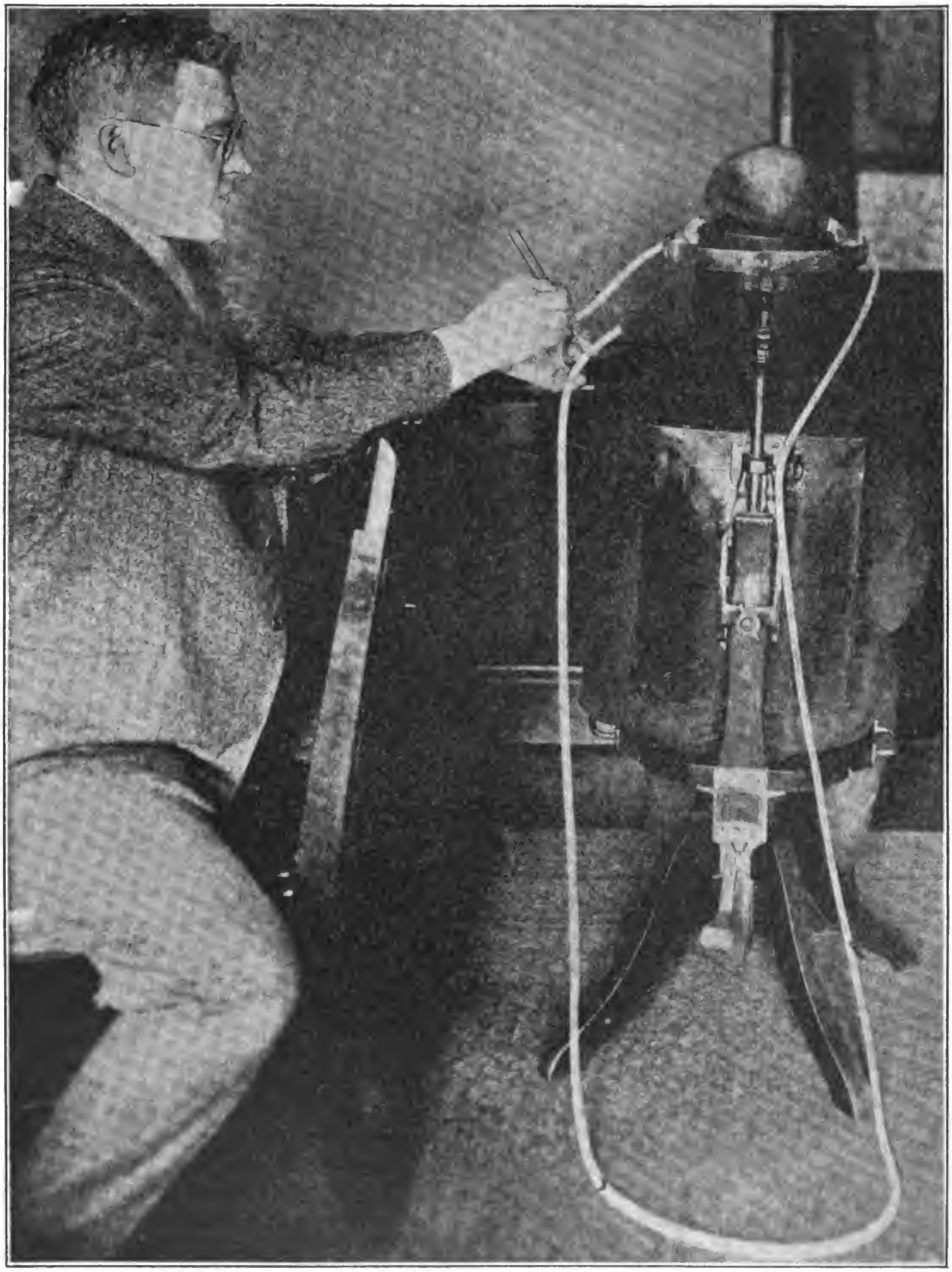
With wounds that are not in the first place sterile, it is suicidal to wait for first intention to operate; for it can go but a short distance before it is interrupted. If the wound is infected, there is no sense at all in carefully bandaging it to exclude infection. As one writer has aptly put it, such a course is as effective as putting a plaster on a wooden leg. The principle of waiting and not interfering, followed with such success in the war of 1904-05, would, if adopted in connection with the war of 1914-18, lead to virulent infections, blood poisoning and gangrenes which would defeat the most experienced surgeons.

BLAZING THE TRAIL

As a matter of fact, in the beginning these factors did defeat the most experienced surgeons. Until Dr. Carrel pointed out in so many words that every wound must be considered infected and treated accordingly, the vast difference between this and previous wars was not realized. Until this far-reaching general principle had been promulgated, the surgeons were really working more or less at haphazard in their efforts to meet the situation with which they were confronted. Nevertheless, they did make distinct progress in these efforts, even in the absence of Dr. Carrel's generalization.

Three periods must be distinguished in the evolution of the sanitary service. In August and September, 1914, on account of lack of means of transport, the wounded came to the surgeons of the base hospitals (insufficient in number) several weeks after having been hit. The wounds, which had been treated by a simple bandage, were in a frightful state of infection. The wounded men were found in piles, already stupefied by infections, their wounds putrid and full of worms. Several French surgeons and the Swiss surgeons, who then offered their services to France, have told of the nauseating odor of fermenting sauerkraut which filled the wards, of pus running through the bandages and the beds, of worms swarming in the wounds. Treatment was almost hopeless, amputation was the only remedy.

In 1914-15, the necessity of operating rapidly on all the wounded hit by an artillery projectile caused the French sanitary service to improvise numerous hospitals in the great centers of the interior. Two or three days



Courtesy of Scientific American.

Testing a Suspected Malingerer With a Tuning Fork

If the malingerer has claimed deafness in one ear, he is made to hear a noise in his "deaf" ear, and therefore claims he does not hear it at all; when the fact is that if he were deaf in the single ear, as he claims, he would hear it in his other ear.

after having been hit, the wounded reached these centers by automobile transport and by sanitary trains. The model of motor ambulance adopted can hold nine wounded men lying on stretchers suspended on springs. The admirable organization of the whole sanitary service in the rear greatly improved the lot of the wounded. The gravest cases only were retained in the hospitals of the zone of the armies. All the others were sent to the interior. No more worms were seen in the wounds, but all the wounds were still infected. Septic fevers and suppuration continued interminably in many cases.

ASEPTIC SURGERY OF THE WAR

The final step is complete freedom from infection. Surgery and bacteriology have demonstrated that wound infection is due to the presence of pyogenic bacteria. Consequently if all such bacteria are kept from the wound, infection cannot result. This demands that we diminish the importance of the hospitals installed in the rear and create in the army zone division hospitals for operating on the wounded without delay. It requires careful sterilization: of metal instruments by boiling; of fabrics by steaming; of the hands of the surgeon by soap, water, and disinfectants, and by the use of rubber gloves; and of the skin of the patient by application of tincture of iodine. Consequently it is the task of war surgery to bring the patient as quickly as possible to a place where these things are assembled, and to assemble them at the most advanced point possible. In general, the most advanced sanitary formation where serious operations can be undertaken is the field hospital. We have seen on the Champagne front, subterranean hospitals, long vaulted corridors covered by several meters of earth, which resisted all the enemy's artillery bombardments. The equipment was perfect; operating rooms, sterilizers, X-ray, and electric light, permitted surgical aid to be given with a maximum of security.

Although the sole cause of wound infection is the presence of bacteria, the latter does not always cause infection, if the body is strong and if the number of bacteria does not exceed a certain maximum of numbers or virulence. War surgery has taken advantage of this fact. Rifle and shrapnel bullets which strike the victim directly do not carry many bacteria, and unless a bone is struck healing is not difficult. In the case of wounds produced by grenade or mine fragments or by bullets which ricochet, circumstances are different. The wounds are larger and more irregular, the tissues are macerated, generally bones are splintered, and, since the missiles have usually thrown up earth or come in contact with it, and much clothing has been driven into the wound, there are many bacteria introduced. If such wounds are bound up at once, inflammation results which may result in necessity of amputation of a member or even death. This fact was not realized at the beginning of the war, but was demonstrated in the first few months. Properly the patient is anesthetized as soon as possible, the wound is opened up, rinsed, irrigated, dressed with disinfecting gauze, for example, iodoform gauze; drainage tubes are inserted to accommodate the flow of the wound secretions; bandages are changed daily. The method of wound sterilization practiced everywhere is that of Carrel, the remarkable French surgeon who distinguished, in peace time, the Rockefeller Institute in New York. This method and its application constitute by all odds the surgical triumph of the war, and are accordingly discussed more fully in another place.

This is very far from the application of the individual first-aid packet that was thought to be sufficient for everything.

WHERE THE SURGEON WORKS

In a war of maneuver, the dressing station, which must be able to change position and follow the movements of the combatants, is established in a house near the firing line, or behind a bit of wall, or in a ravine sheltered from rifle bullets if not from shell. In these rudimentary establishments, often under fire, the surgeons perform prodigies. They stop hemorrhages which would else quickly prove fatal, clean wounds, place temporary apparatus which permit the patients to be moved to the nearest field hospital; give injections of ether, caffein, and serums to revive those who are fainting, and injections of morphine to ease those who are suffering.

In the type of warfare developed in 1915,

however, the stationary character of the fronts permitted the installation, near the firing line, of well-organized dressing stations, which although under fire are sheltered. In defiladed shelters dug in hillsides, or deep into the earth—huge, carefully planned caves—were placed litters and beds. Well-lighted operating rooms permitted major operations of surgery, such as locating and suturing abdominal wounds; performed a few hours after the injury, soldiers were saved whom operations performed later could not save. These patients, as soon as their condition permitted, often the following night, or sometimes several days later, in cases of wounds of the cranium or the abdomen, were removed, when possible in automobiles, to the nearest field hospital station.

These field hospital stations to which the wounded were taken from the dressing stations were of various types, according to the resources available in the locality. Some were in barns, others in country residences, in large tents, in big hotels. They were brought to a high state of perfection as the war proceeded. The motor hospitals constituted a great step forward. They permitted us to take our operating rooms rapidly to the scene of combat; in them, skillful surgeons performed all the important kinds of modern operations.

THE SURGEON AT WORK

A Few of the Things He Was Asked to Do, and a Few of the Ways in Which He Did Them

ALTHOUGH in the Russo-Japanese War the wounds of the head and neck represented fifteen per cent. of the injuries suffered by the men actively engaged, these wounds are of far greater frequency in the trench warfare into which the recent war degenerated. The adoption of the helmet saved a great number of men from injury, and converted in many other cases what would have been certain death into wounds that could be treated with success. The showing of the helmet is that even when a direct hit is made, piercing the metal, the effect upon the skull inside is altered from a penetration to a crushing. This is met with comparative ease by trepanning. The wound is enlarged, the hole in the bone trimmed, the pieces of bone removed, the brain drained—and after all this the patient recovers!

A fundamentally important thing to remember in considering injuries involving the cranium and the brain is that injuries to the cranium are of importance only as they expose or injure the brain and its membranes. In the second place, it must be remembered that anatomically the cranium is a hollow shell with sufficient elasticity to bend and rebound. Thus injury may result in local bending with lesion at or under the point of contact; or it may result in a bursting of the wall opposite the point of contact with a consequent distant lesion; or, lastly, the injury may result from the expansive force of a missile passing through the skull at a high velocity.

Here we may point out that the resistance of cerebral matter to infection shown by the war is extraordinary—certainly one of the most curious medical facts brought out by the war. The medical press has told of a great number of wounded cured of a suppurative hernia of the brain caused by a fracture of the skull. The extruded portions of the brain are actually removed, and apparently without ill effects! A case is recorded of a man whose cerebellum was literally bathed in a lake of pus; yet he was cured after a few weeks' drainage. But the surgeons have learned to mistrust small grazings of the skull which do not appear to be serious. In such cases the inner surface of the bone is often damaged, and if proper repairs are not made, the irritation of the cerebral envelope after a while leads to epilepsy. So the most insignificant-appearing head wounds are now trepanned systematically.

WOUNDS OF THE FACE

Looking out of the loop-hole or peering about a corner of some protecting body, the soldier is often hit in the face. The eye is shot from its orbit, or the face below is seriously mutilated. Such wounds are particularly impressive in their appearance; apart from the fact that a mutilated face is a more horrible spectacle than a mutilated arm or leg, the face tissues are very full of blood vessels and very elastic. They swell and become deformed, on this account, more than the tissues of any other part of the body.

Such wounded are taken, after preliminary recovery, to special hospitals fitted up for plastic surgery. Among these may be mentioned the ones at Paris, Lyons and Berlin. During the period of infection and elimination of morbid tissue the wounded who have had the lower part of the face torn away must be fed through a tube. A man who has lost his entire mouth and chin can be kept alive in this fashion. When the healing process begins, the surgeons graft in a piece of leg bone or rib, from which a jaw is improvised with a good deal of skill. Cheeks are usually supplied by strips of skin taken from the arm. Mutilated noses are again made fit for human society by the kindly offices of paraffine injections.

THE CHEST AND ABDOMEN

Rifle bullets frequently go clean through the thorax without producing infection. If the pulmonary tissue is only pierced, the treatment is surprisingly direct and simple. The wounded man generally survives the immediate hemorrhage; a puncture of the pleura then evacuates the blood, the anguish produced by difficulty in breathing disappears gradually, and the patient is fit for service again in a few months. Shell fragments cause much more damage. They lacerate the lung and provoke infections. Death from blood poisoning is prevented only by cutting a hole in the ribs and draining on a large scale. An aspirating machine empties the pleura of pus as it forms.

The possibility of carrying out prolonged operations within the chest cavity, while not an actual development of the war, is comparatively new and has been greatly extended by war experience. Indeed, we recall, so recently as 1907, a tolerably competent physician who scoffed at newspaper reports of such operations, pointing out that they could never be effected because of the inevitable collapse of the lungs upon opening the chest cavity. Of course this is overcome by a mechanical appliance for maintaining the proper pressure within the cavity, about the heart and lungs; and it is no longer unique for a surgeon to operate upon the heart itself.

LESIONS OF BLOOD VESSELS AND NERVES

The chief danger in local wounds of blood vessels is that the blood from the artery, with its higher pressure, will penetrate to a neighboring vein and distend it beyond its elastic limit. Proper dressing minimizes this; and for the anemia that occurs when it is not prevented, blood transfusion is the remedy. It is even suggested that we may take a leaf out of the books of some of our lurid fiction writers, and in the next war maintain in the hospitals a class of earnest patriots, who are disqualified from other service, for the express purpose of giving up their blood to men from the theater of action.

Pressure on the spinal cord may be produced by a wound, and requires the most delicate treatment. An interesting case of this, observed to considerable numbers in the war, arises when a large shell bursts near a man without wounding him. The man frequently falls unconscious and remains so for eighteen hours or more. On awaking, the muscles about the backbone and neck are contracted, the hands are clenched, the skin and scalp are unduly sensitive; the patient remains dazed for several weeks, sleeping hardly at all and eating little. In some cases there is paralysis on one side. In the beginning these symptoms were put down to hysteria; it was eventually found, by puncturing the spinal column, that there was hemorrhage of the spinal fluid which brought pressure upon the cord. Repeated puncturing always gives relief and sometimes cures entirely.

When a nerve is severed, the cut ends are sutured together. The restoration of nervous conductivity is not observable at all for six to eighteen months, and then proceeds but slowly; frequently it is never complete.

FRACTURES

Shell fragments and shrapnel bullets play sad havoc with bones. Their effects cannot be described other than as mashing. Such wounds must be cleaned and drained with the utmost care. Prompt immobilization being a first requisite for a good cure, the showing made with these cases improved as the war went on. A great deal of trouble was experienced with adhesions—this being the doctor's term to indicate that, in the rearrangement of bones and muscles incident to the knitting of the re-set bone, a tendon has taken hold of a bone where it does not belong. This is the cause of the stiff joints which are such a feature of bad surgery; and it is one of the conditions which is met and defeated by the mechano-therapy described in another chapter.

A curious psychological quirk is that the doctors find it desirable to deprive the leg cases of crutches. When these are furnished, the men get quickly to a point where they can navigate with them, and then cease improving; the crutch becomes the goal of their ambitions. In the absence of crutches, the patients display a little more hesitation about first trusting themselves on their feet; but after they have begun to hop about on one foot or to hobble with a cane, they carry their recovery along much more rapidly and to a far more advanced point.

Fragments of bone are subject to the general law that all infected foreign bodies must be removed from the organism. So long as a particle of dead bone remains in a wound, suppuration will continue and healing be out of the question. The rifle bullet, on the other hand, which as we have seen is usually sterile when it enters, is tolerated by the organism. If it does not offer any mechanical hindrance to free movement, the patient may choose whether it shall come out or not. In France the decision was usually in the negative, because German bullets generally were found to have fragmented very extensively, so that it was out of the question to get them out altogether, or to find a single piece that amounted to anything as a souvenir. On the other hand, in Germany the question was more often decided in favor of extraction, since the French and British bullets were apt to deform without breaking up. Especially in the Baden hospitals the wounded always asked for their bullets, because the Grand Duchess had them silver-plated and returned them to the men for use as watch charms.

INFECTION AND WHAT IT MEANS

Before this war, when amputation was effected, strips of the flesh were cut to fold back over the cut and make a good stump. But the gravity of the present wounds has forced the surgeons to return to the methods of Napoleon's time, and the members are now cut off flush, leaving the surface exposed after tying up the blood vessels. This is the only reasonably certain method of guarding against an ascending infection.

Another very grave complication of infected wounds is tetanus, which was very frequent at the beginning of the war, until measures for its cure were suppressed in favor of preventive action. This microbe lives in the soil as a spore. Hence in bad weather he is particularly dangerous, because it is then that the chance is greatest of the projectile's carrying into the wound particles of mud from the clothes. The sooner tetanus appears after a wound the more serious it is; the tardy cases are usually easy to deal with. Experience soon showed that it was absolutely ineffective to inoculate against tetanus after the appearance of the infection; the germ has then got such a start that no serum can ever catch up. So tetanus injection is given all wounded before they leave the trench—in other words, at the first possible moment after they are hit; and this prevents the development of the infection in very satisfactory manner. It is found, however, that when projectiles are extracted several months after the wound, the effect so far as tetanus is concerned is quite that of a fresh exposure, and the original injection is no longer effective; so a new injection is given before removing metal from an old wound.

Gas gangrene, terrible as it was in the early days when its nature was not clearly understood, does not deserve to stand in a class by itself. It is strictly a germ disease, and is attributable to the gas only in that the gas constitutes the favorable environment which this particular germ requires for its development. Wide opening and systematic drain-

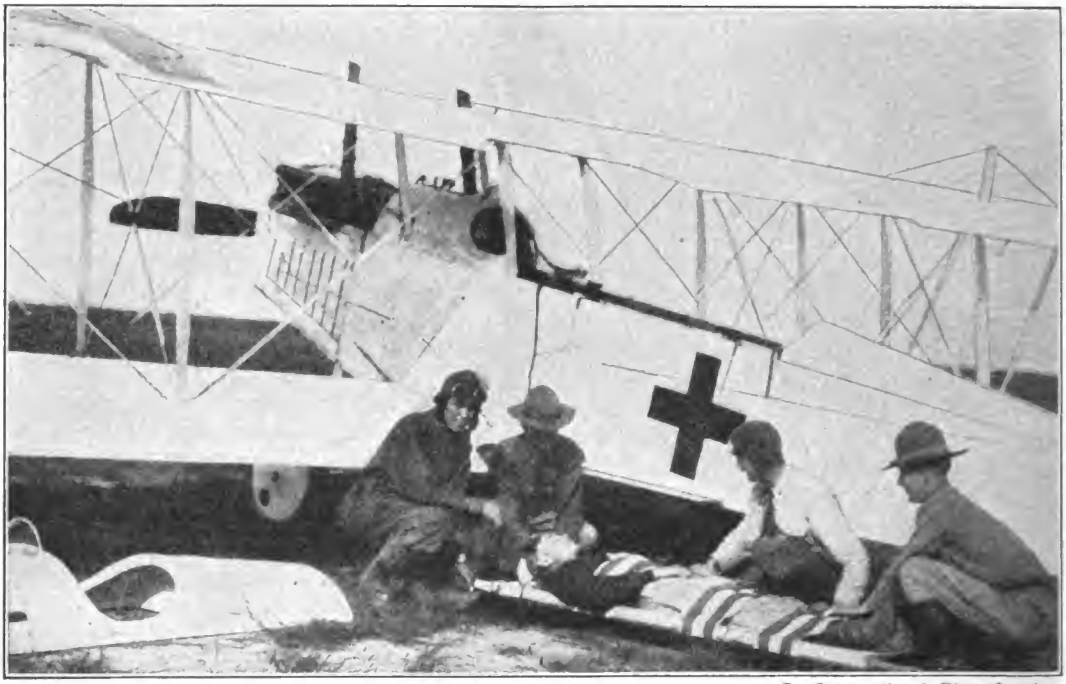
age of any wound which has been exposed to gas is adequate to insure that this infection will not appear.

"SHELL SHOCK"

The symptoms to which this name has been applied are extraordinarily varied; but they can be well generalized by saying that they involve the loss, without apparent reason, of some motor or sensory or mental function. Originally it was supposed that a shell must burst very close to a man to lead to this effect; and the direct cause was localized in the violent concussion. But men are frequently brought in unable to speak or to see or to hear or to remember or to reason, or suffering from various forms of local or general paralysis, or in various stages of violent dementia, who have been without any such immediate shock. Accordingly it is necessary to recognize shell shock as a more distinctly nervous disorder, induced not by specific shock or even by so definite a cause as long continued din, but attributable rather to the general conditions of high nervous tension under which the men live for every instant at the front.

As a matter of fact, the theory that was gaining ground at the close of the war was that shell shock is a subconscious reaction of the patient to these conditions. There can be no two opinions about the character of trench life and the intense desire of every man to get away from it. In the case of a man with a broad yellow streak, a conscious and deliberate effort is made to escape by claiming a disability which does not exist, or in an extreme by a self-inflicted wound. In the case of men who are above this sort of thing, but lack the power to drive themselves to the last notch, the nervous system assumes control of the situation and makes the man an unconscious malingerer. He is unable to remember because he really does not want to; and usually the cure lies in convincing him that the matter is thus at his command.

Isolated cases of the same phenomenon have been reported from civil life. For instance, one man whose marriage had turned out to be a most unfortunate one brooded so hard over



Airplane Ambulance

Showing how a wounded aviator can be cared for by his flying brothers.

it that his desire never to see his wife again led to blindness through self-hypnotism. His organs of vision were absolutely all right, but the optic nerve responded to the central idea in his mind and ceased to function. Just so it is with the subconscious malingerers who develop shell shock. The man carries on to a certain point, and then some or all of his overwrought nerves take hold of the matter and go on strike.

The treatments proposed for shell shock have been various. The English go to an extreme of coddling these men, apparently because they recognize that unpleasant conditions have led to the malady. But this is not effective, because there is no inducement offered the nervous system to come around to normal again. The French, with a dim idea that the patient was at least deceiving himself if not actually the doctor, have employed the rather violent process of *torpillage,* or torpedoing the victim of shell shock. He is subjected to an extremely severe and painful electric shock, which generally brings him around in quick order, but which is needlessly cruel. Between these two extremes all sorts of compromises have been tried or proposed; but the fact is that each case should have individual attention, just like any other case of insanity or nervous breakdown. In the American hospitals for returned soldiers the men got this individual attention, with the result that patients who had at first to be confined in straitjackets were sufficiently improved after a few weeks to go outdoors unattended.

CURING WOUNDS BY FORMULA

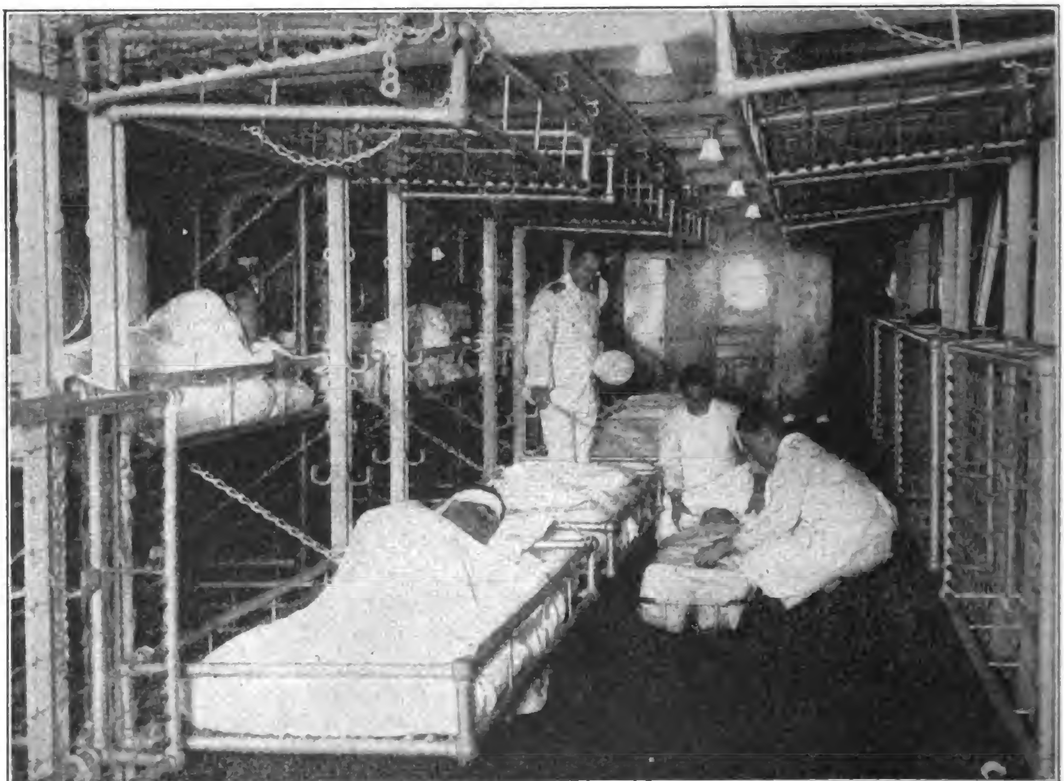
The Outstanding Surgical Triumph of the War as Achieved by Drs. Carrel and Dakin

THE surgeon's efforts to cure wounds resolve themselves into a constant fight against infection. If it can be assured that a wound will become and remain sterile, it will heal by nature's own process of "first intention" in marvelously short time. But in dealing with battle-stricken soldiers, the medical man has had to measure forces with the insidious workings of infinitesimal micro-organisms, and these have in hundreds of thousands of cases wrought havoc out of all proportion to the original extent of the wounds. Virulent bacteria have aggravated relatively trifling hurts, and have radically altered the problem of the military surgeon.

Nature has given us in our bodily cuticle a natural defense against the billions of germs that lie in wait for us at well-nigh every turn. Most of us little realize it, but every break in the skin is a breach through which bacteria may penetrate our physical stronghold and possibly drive us to the wall in a feverish struggle for life. Fortunately, we dwellers in civilized communities have become immunized in large measure to many of the micro-organisms that surround us. Not so "over there," because the bacilli that lurk upon the battle ground are those of tetanus, gas-gangrene, and certain putrefactive organisms. They are there in noxious abundance simply because of the character of the fertilizers that have been strewn upon those erstwhile productive acres to make them fruitful. No wonder, then, that infected wounds greatly predominate.

Accordingly, if he be stricken in the trenches or thereabouts, it is next to impossible to safeguard the soldier by precautionary measures against the inoculation of one or more types of these bacilli. The best that can be done to help him is to neutralize the action of the micro-organisms and, *accepting their presence,* to destroy them before they can gain the upper hand against the natural resistance of the body and the coöperative labors of the surgeon. This is just exactly what Doctor Alexis Carrel of the Rockefeller Institute of Medical Research initiated in the first year of the war, just back of the Western Front in France.

Doctor Carrel recognized shortly after he joined the French ambulance service that the surgeon's task would be a hopeless one as a rule if he could not find a way to sterilize infected wounds. The problem was not that of applying the traditional ounce of prevention but of resorting to a pound of cure that could be relied upon to do the delayed work well and thoroughly. Theoretically, this scheme of treatment was directly opposed to that advocated by the conservative members of the medical profession, who for many months after the outbreak of hostilities could not bring themselves to realize that peacetime surgery and wartime surgery differed in some profound respects.



© Paul Thompson.

View of Ward on the U. S. S. *Mercy*

The *Mercy* was a hospital ship used to bring back our badly wounded soldiers from the other side.

THE PROBLEM OF ASEPTIC SURGERY

Undeterred by the criticism of his confreres, Doctor Carrel pursued his investigations; and out of the months of patient, painstaking, and exact researches carried out by him and his associates, was evolved what is generally known as the Carrel-Dakin treatment for infected wounds. The thing sought was a germicide that would be equally fatal to all micro-organisms carried into a wound and yet which would be so mild in its operation that it would not irritate the raw surfaces of the injury. This was a pretty large order, and it is not surprising that more than 200 sterilizing fluids were tested before hypochlorite of soda was chosen. The essential problem was to free it of certain irritative alkaline ingredients.

The hypochlorite solution, while benign in its action towards the wound surfaces, nevertheless is destructive to micro-organisms and able to dissolve and to detach dead tissues—thus removing mechanically the breeding places and retreats of the bacilli. The erosive

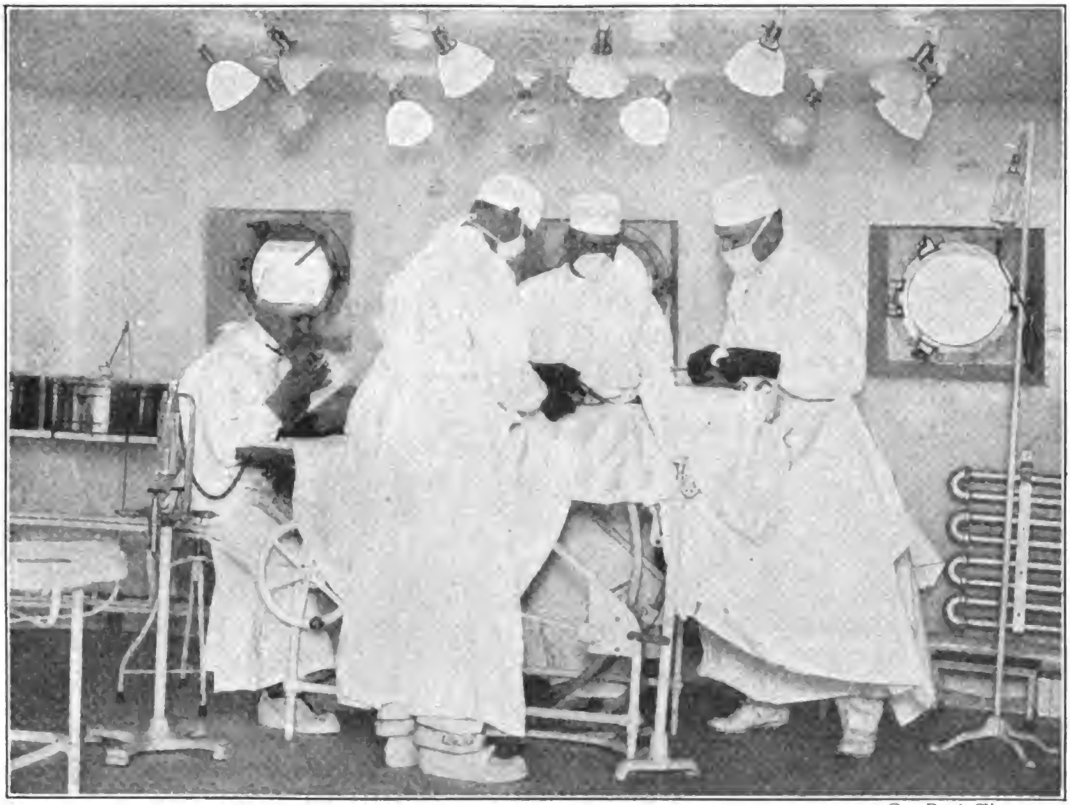
work of the germicide invariably ceases when it reaches vitalized body substance, and, therefore, does not provoke secondary hemorrhage.

HELPING TO CURE A WOUND BY MAKING IT LARGER AND DEEPER

It is absolutely essential to success that the wound, particularly if a deep one, be opened up freely by the knife in order to remove bits of clothing, fragments of shell, blood clots, and splinters of bone which otherwise would form microbial nests. When the damaged area has been satisfactorily cleansed by means of the hypochlorite, the healthy granular surfaces can be brought together and healing accomplished without further complications, in the presence of the sterilizing solution.

For the safe and sure achievement of this end, Dr. Carrel has designed a tube system by which thorough irrigation of the deepest wound is made easy. This consists of a trunk tube with a number of branches, closed at the ends, but perforated along their lengths. When these are arranged in the wound, the operator is able, by simply pressing the bulb which connects the main tube with the source of supply, to force the antiseptic fluid into every part of the affected tissue. This irrigation is performed for about two hours daily.

This treatment must be continued until the injury is indubitably sterile from a surgical viewpoint; and the surgeon cannot depend upon his unaided eye—as was heretofore the common practice—to decide when the injury can be closed. Here Dr. Carrel has introduced another novelty.



Operating Room on the U. S. S. *Mercy*

Showing the modern equipment which was used.

MATHEMATICS AND SURGERY

The bacteriological condition of the injury must be established by a microscopic examina-

tion made every two days. Secretions are taken from several parts of the raw surfaces —particularly those where bacteria would find securest lodgment—and smears are made upon thin strips of glass. The smears are dried and then stained to make the micro-organisms more readily discernible. The number of germs in each microscopic "field" of 1.8 mm. is counted, if they do not exceed fifty or 100. The tally is recorded upon a bacteriological chart, and thus, day by day, the attending physician has a sure indication of progress toward sterilization. Finally, when the microscope discloses but one germ in five or ten fields it is safe to close the wound without fear of reinfection.

But the surfaces of the wound may give microscopic evidence of sterility and yet the injury be, in fact, infected. How, then, does Dr. Carrel guard against overhaste in closing? Here is the phase of the problem where mathematics comes into play. This surgeon-scientist discovered a decade ago that a wound's rate of healing in a healthy person is determined primarily by its initial area. At his hospital at Compiegne, France, this phenomenon was subjected to searching study, and Captain de Nouy, a physicist, evolved a formula which gives an algebraic value applicable to the average patient with an uninfected hurt. That is to say, by this formula it is practicable to foretell the day of ultimate closure and to determine the diurnal rate of healing or repair. This is based upon the area of the injury at the time of first observation, and from that measurement is developed a so-called "control curve" by which the subsequent repairing of the wound is checked up.

Every four days the area of the wound is remeasured. This is done by making a tracing with India ink upon a sheet of thin sterilized celluloid which is laid upon the hurt. The contour thus established is transferred to paper and the area ascertained by means of a planimeter. The figure obtained is plotted and if the rate of healing as thus revealed is found to vary in a marked degree from that of the control curve, the lag is a sure sign that the injury is infected. If this infection is not upon the visible surface of the hurt the surgeon must explore for it. The seat of trouble will then be found in some recess or by-path of the wound which has escaped notice and been beyond the reach of the liquid germicide. The bacteriological chart and the repair graph must, therefore, agree in their general index of progress, and the surgeon has by these means a check and a countercheck upon the healing processes.

THE SHORT STEP FROM WAR TO INDUSTRY

While originally conceived to aid only the battle stricken, the Carrel-Dakin treatment is rapidly proving its value in both civil and industrial surgery. A number of our biggest manufacturing concerns have adopted the treatment for the injured at their works, and the results are certainly a revelation. Then in ordinary surgery, the Carrel-Dakin treatment of infected wounds has been of marked success in a wide range of maladies—such as appendicitis, peritonitis, mastoiditis, puerperal fever, etc.; and its application is daily widening. Thus insidious micro-organisms are being dealt with effectually, the work of the knife is being reduced accordingly, and the patient is returned to health and strength with a minimum of mutilation. Not only that, but an aftermath of reinfection is effectually prevented and recovery achieved in a remarkably short while. Such is one blessing born of the war.

THE WAR AND THE PUBLIC HEALTH

One of the notable benefits of American participation in the war was the great advance made toward a general acceptance of the elementary standards of hygiene. Four million men were more or less completely inducted into the army. These men were subjected for greater or less periods to military discipline, which includes scrupulous attention to all matters affecting health. The majority of these citizen soldiers had never before come in contact with organized sanitation; hundreds of thousands had never had an adequate physical examination. Not only were they forced into habits of cleanliness and health, but they were given opportunity to see that these habits paid. They learned something, at least, of the mechanics of contagion, and went back into civil life with a far better idea how to protect their own and others' health than they had ever had before. This is one of the things that is meant by universal military training.

EXPLORING WITH THE X-RAY

How the Shadow Picture of the Fluorescent Screen is Made to Tell the Precise Location of Bullets in the Human Body

IN another place it is pointed out that it is frequently a matter of personal choice on the part of the wounded man whether the bullet shall be removed or allowed to remain where it lies. But there are many circumstances under which the intruding bit of metal occupies, with reference to some blood vessel, nerve, muscle or other organ, a position sufficiently dangerous or sufficiently inconvenient or sufficiently painful to call for its elimination. In this event the first step is location; and since the bullet wound, distinguished from the shell wound, does not have to be widely opened in the course of treatment, it is desired to avoid the necessity of opening it for exploration in search of the bullet. Therefore the X-ray is indicated.

Now, the layman understands in a vague manner that the X-ray is an instrument for making the insides of things visible. Probably a good many laymen would agree that it is an instrument for looking through things. But few laymen know that in the X-ray perspective is altogether lost, that all you see in a print or in an image thrown upon the screen is a sort of shadow picture. If it be the thigh that is under examination, there is a vague shadowy outline of the flesh, which increases in depth as the flesh increases in thickness; in the middle of this there is a darker channel which marks the position of the bone; and somewhere there may be a spot of comparatively dense black corresponding to the bullet. But the whole thing is strictly a map or plan view; the relative horizontal positions of flesh, bone and bullet are shown, but there is absolutely no indication as to depth. If it happens to be possible to cut straight down in the direction from which the picture was taken, this can be done with assurance that the foreign substance will eventually be reached. But when this is not possible, it is an altogether puzzling matter to decide at just what angle to cut in from some other point in search of it.

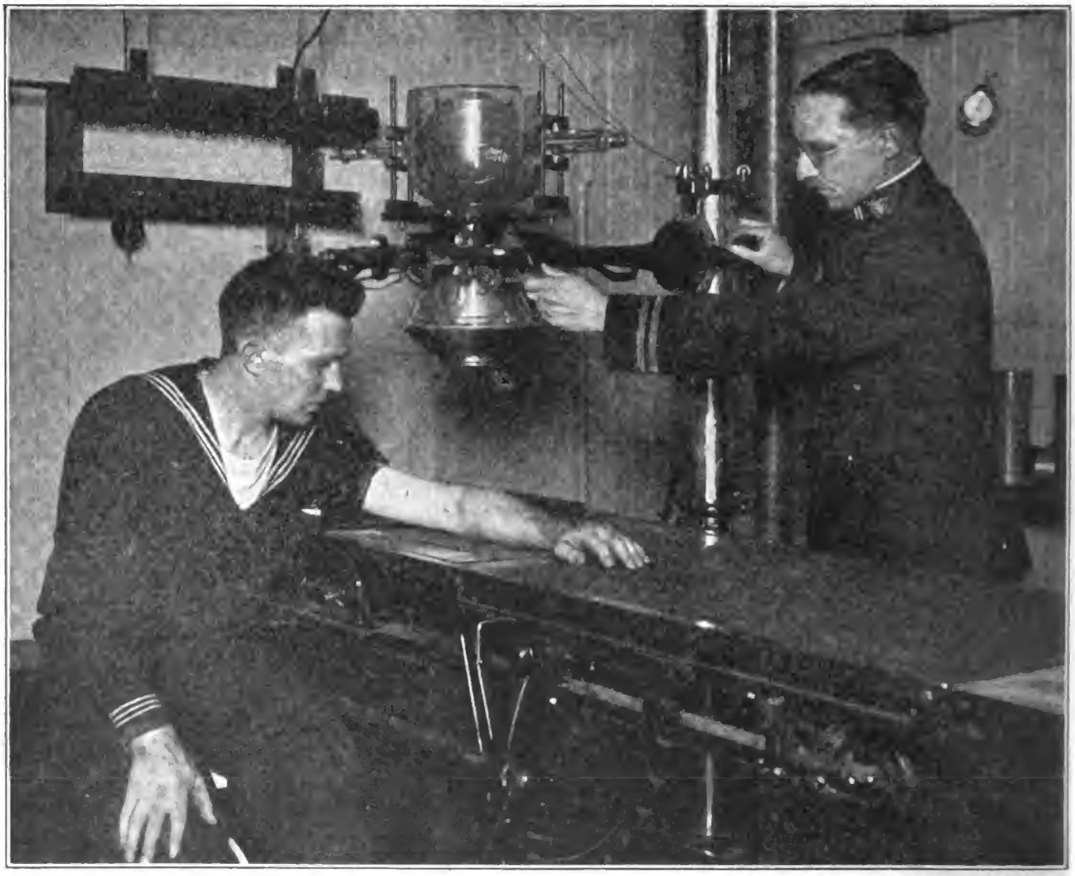
DIFFICULTIES OF THE SHADOWGRAPH

As a consequence, when we employ the X-ray in search of bullets in the human body, we must have some special apparatus which gets away from this inherent defect. The obvious thing to do is to take two shadowgraphs, which will show the relative position of the bullet in two different planes, so that the two observations can be combined in such fashion as to reveal its exact hiding place. Now it happens that when we do this we consume a vast amount of time unless the apparatus is so arranged as to combine the two views mechanically. Of course this makes it out of the question to take and develop X-ray photographs; what we have to do is employ the fluoroscopic screen, upon which the shadowgraph is thrown in such a way as to be visible to the eye. Then the apparatus combines two such readings in such a way as to tell us precisely where to search for the bullet.

In spite of its universal employment, the fluoroscopic method has not been on an altogether satisfactory basis. The number of trained and experienced radiologists is far below what is needed. Worse, the number of devices in current use has been approximately equal to the number of expert radiologists at work, since most of these men employ either their own devices or their own modifications of some one's else device. While all are accurate enough, making use in some form of the familiar principle of triangulation, the large majority are complicated, and require for their proper use a technical knowledge and skill not possessed by the ordinary operator. Moreover, the knowledge and skill sufficient to run one of them may not be just the knowl-

edge and skill that will run another—the old, old drawback always found in lack of standardization. In addition to all this, with many of them the time required for localization is too long for them to be of very great service except at base hospitals in the rear, where time is not such an absolutely vital factor.

Accordingly, in spite of the comparatively large number of devices already in use, there seemed to be plenty of room, at the entrance of the United States in the war, for one which would be simpler in construction and especially simpler in use, so that any physician, regardless of lack of previous experience with the X-rays, could master the technique in a short time; and it seemed above all that one might be developed requiring so few manipulations that the localization could be accomplished with it in a very brief interval. A good many American doctors and physicists therefore turned their attention to the problem; and as the result of experiments carried on in his laboratory at Tulane University, Dr. Amedee Granger presented a device which seemed to fill all the requirements of accuracy, simplicity and speed. As an excellent example of the sort of apparatus necessary for bullet location, the principles involved, and the type of improvements sought, we can do no better than describe it.



© *Paul Thompson.*

An X-Ray Apparatus in Operation

On board the United States Hospital Ship *Mercy.*

The general construction is that of a vertical stand on a horizontal base plate. A little square hole in the base plate is crossed by perpendicular bars which, with the sides of the hole itself and with longitudinal markings on the bottom of the aluminum plate,

make a gridiron pattern whose shadow is seen on the fluorescent screen. The latter is not a part of the apparatus proper, but is put in place separately and held rigidly from a separate stand. It goes above the patient, while the base plate of the localizer goes beneath him. A pointer, which moves up and down on the vertical arm, it should also be specified, is exactly in a vertical plane with the central longitudinal bar in the little square hole.

HOW ONE LOCALIZER WORKS

To locate a foreign body it is necessary to have, besides the assembled localizer, a transparent-top table and a holder or box of some kind for the X-ray tube, provided with a diaphragm. Then there must be some arrangement for moving this holder under the table, as well as for fixing it in a given position. The range of this movement need not be great; a foot will suffice for every possible case. The patient is placed on the table, the wounded part lying over the X-ray tube-holder, and the fluorescent screen is put in position above him.

The diaphragm of the tube-holder having been previously closed so that there appears upon the screen a circle of fluorescence no more than two inches in diameter, the tube is shifted about until the shadow of the foreign substance is seen lying in the very center of this bright area. It is understood that the localizer has not yet been put in place.

This is now done—the base plate is slipped under the patient; and it is moved back and forth until the shadow of the intersection of that part of the grid within the square hole falls accurately upon that of the bullet.

The diaphragm of the tube-holder is now opened, so that the shadow of the complete gridiron appears on the screen. The shadow of the pointer must necessarily fall along that of the long central bar. The tube is then moved until the shadow of the foreign body leaves that of the central point of the cross and moves over into an identical position with reference to the shadow of one of the lateral guides. This shifts the shadow of the pointer also; but as the pointer itself is not at the same height as the foreign substance in the patient's body, it will not move the same distance, but will take up an undetermined position somewhere between the central and the lateral guides.

As the last step in the adjustment of the localizer, the pointer is now moved up on the vertical standard, by turning the little thumb-screw, until its shadow does fall centrally upon the lateral guide.

The situation is now at the operator's mercy. For the pointer in its final position lies on the same horizontal plane as the bullet, while the latter is directly above the center of the grating. Accordingly the intruding bit of metal is precisely located at the intersection of two imaginary lines which may be projected through the patient's anatomy. To facilitate the subsequent operation, these lines are plainly indicated; the pointer is pushed forward to make one mark on the skin, while a little needle is thrust up from below, through a tiny hole in the intersection of the central ribs in the square hole, to make another mark; and this gives a record of the bullet's position which cannot be misinterpreted.

These points can be marked later with nitrate of silver, but even this is not the extent of the certainty which Dr. Granger's localizer affords the surgeon. For the horizontal and vertical scales indicate the distances of the bullet from the two marked points, so that the operator does not have to reconstruct in his imagination the lines through the patient's body joining these points. He can cut straight in from either point to a known distance in the secure knowledge that at that distance he will find the fragment he seeks; or if it is expedient to cut in from some other point, he can in a moment calculate how far he will have to penetrate from there.

THE X-RAY TAPE MEASURE

Any effective X-ray localizer must operate upon these same general principles; the variation is in the details only. And it will be understood that in order to get accurate indications of the location of a foreign substance in the body, some such special apparatus as that of Dr. Granger must be employed. The X-ray picture is a shadowgraph, and accordingly a single print or screen image cannot give unaided any more than an indication of direction. But in order to use the X-ray with effect it is not always necessary to have so

much apparatus; witness a rather unusual outfit suggested by an officer of the Medical Reserve Corps. The novelty consists in the means taken for overcoming the fundamental deficiency of the shadowgraph—namely, that it conveys no information about distances. It is proposed to place about the patient's trunk or limb, as the case may be, a flexible metallic tape measure, the calibrations and the numerals marking them being perforated in the metal. These calibrations will, of course, then register on the shadowgraph, leading a very obvious aid to the mathematical work of measuring the depth of the intruding body.

The designer of this novel apparatus has paid a good deal of attention to the mechanical details. He suggests that the bands be illuminated with radium paint for working in the dark room and for adjustment in the dark at the hands of the fluoroscope operator. He points out that the bands, when anchored in place by adhesive tape, may be left on any part of the body for any length of time. When this is not desired, the calibrations may be marked on the patient by nitrate of silver or luminous paint, just as in the more usual procedure of Dr. Granger and others in his class.

MOVING THE WOUNDED MAN

Some of the Conveyances in Which He Travels from the Time He is Hit Until His Case is Disposed Of

PERHAPS the greatest single problem that confronted the Army Medical Service was the necessity for transporting, over varying distances, soldiers suffering from wounds and sickness of varying severity. Indeed, the handling of wounded men bears a striking resemblance to the great system of collection and distribution which is necessary for the feeding of a nation. Like food, the wounded had first to be gathered up from all sorts of places, a few at a time, and passed along from one point of concentration to another, until they reached the base hospitals which were the neck of the bottle, corresponding to the great packing houses which handle all our food *en route* from producer to consumer. Here they were worked over and sorted out afresh, just as is the food in the packing house; and finally, in further pursuit of the analogy, the process of distribution commenced—the men were sent home or to centers of special treatment or to points where they could render limited service or back to the front to rejoin their original units.

Now in bringing foodstuffs to the packing house, and in distributing them among the wholesaler, the retailer and the consumer, the outstanding problems of transportation were those that had to do with routes and power; few commodities call for extreme attention in the packing. But in distributing sick and wounded men to the places where they should go, the controlling consideration was that these men should be packed in suitable—we had almost allowed our analogy to betray us into saying containers, where we mean conveyances. From the moment when a man was picked up on the field of battle until the time when he passed out of the hands of the army physicians, there were stretchers and ambulances, trains and ships, designed for the express purpose of carrying sick men and wounded men.

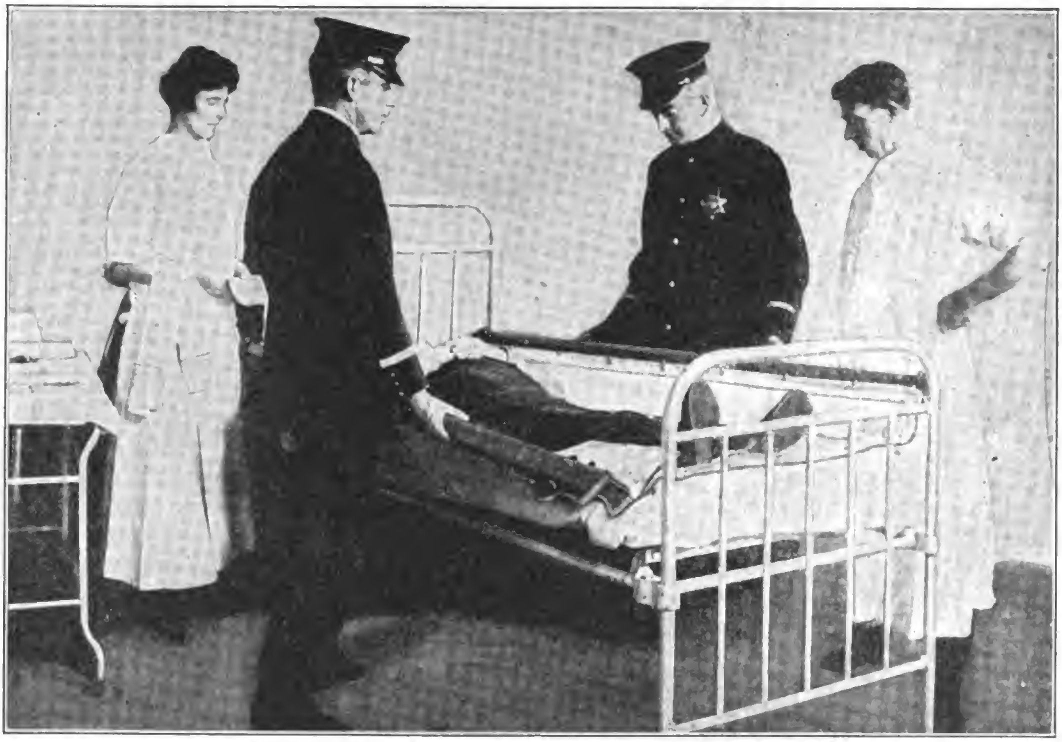
HARVESTING THE CROP OF CANNON FODDER

The first essential was proper transportation from the scene of the casualty to the first-aid station, and thence to the hospital. The motor ambulance, in spite of the wonderful feats of bravery performed with it, was after all a commonplace in a scientific and technical sense; it need not be discussed here. But the ambulance was merely the means that we liked best to use; it was far from being the means that we were universally able to use. Under the adverse conditions encountered on the battlefield, it is obvious that the

local transportation of wounded to places of shelter frequently took on queer forms. It seems that no end of vehicles were tried from the beginning of the war.

In the Balkans the British hospital men made use of a double-decked litter. This was swung between two donkeys, and because of the mountainous nature of the country it was said here to be the ideal. Down in the Holy Land, where in place of the mud of Flanders or the rocks of Macedonia we have vast expanses of sand, other devices were employed. Here the British had good success with sand sleds, drawn by horse, mule or camel. A canvas cover was of course provided to protect the passenger from the burning rays of the sun.

For the transportation of the wounded on the battlefields of the main front in France perhaps the most common of the numerous and diversified transportation methods was the good old hand stretcher. But it is really surprising what a scope for invention this time-honored friend of the wounded warrior presented. The object, of course, was always to safeguard the bearers and the burden. An easier journey was often afforded the wounded man by mounting the stretcher on wheels, where the nature of the terrain to be crossed made this worth while. Another step in advance was rather of interest to the bearers —the double-decked stretcher enabled them to carry twice as many men with the same risk, or the same number of men with half the risk.



Courtesy of Scientific American.

An Improved Stretcher

The folding handles reduce the length, making possible its delivery to a hospital bed.

WHAT THE INVENTOR CAN DO TO THE STRETCHER

Still another way to minimize the risk lay in the direct effort to expose the stretcher bearer less to the hostile fire. We recall a problem in our calculus, our inability to solve which in a hurry almost cost us the proud rank of prize mathematician of our Freshman class, and which read about as follows: a pas-

sage eight feet wide opens out of a passage twelve feet wide. Neglecting the width of the girder, what is the longest girder which will go around the corner? In carrying wounded men on stretchers through intricate trench systems, this identical problem arose; and if the stretcher happened to be too long, as was frequently the case, the consequences were serious. It was out of the question to lift a *grand blessé* off and on the stretcher several times in the course of a trip to the first-line hospital, so the only alternative was to hoist him clear of the trench for a moment, and negotiate the turn with the stretcher and its occupant exposed to the enemy fire. So an American army doctor came to the rescue with a swiveled-end stretcher which would take a sharp corner in three segments, and thereby obviate this difficulty; and his clever invention was officially adopted for use in France.

Still another amelioration of the hard lot of the wounded man who was to be conveyed from the scene of his misfortunes was effected by the installation of a painless way of loading and unloading him aboard his stretcher. In the strides made during the past decade by medical science and surgery, little attention had been paid to this minor, but none the less urgent, point in the moving of the injured. Every doctor will concede that the current style of handling patients in this transfer led to irritation and shock which, in severe cases, became a serious complication. But there had been no suggested means for avoiding these unpleasant consequences.

© Kadel and Herbert.

Dog-Drawn Ambulance

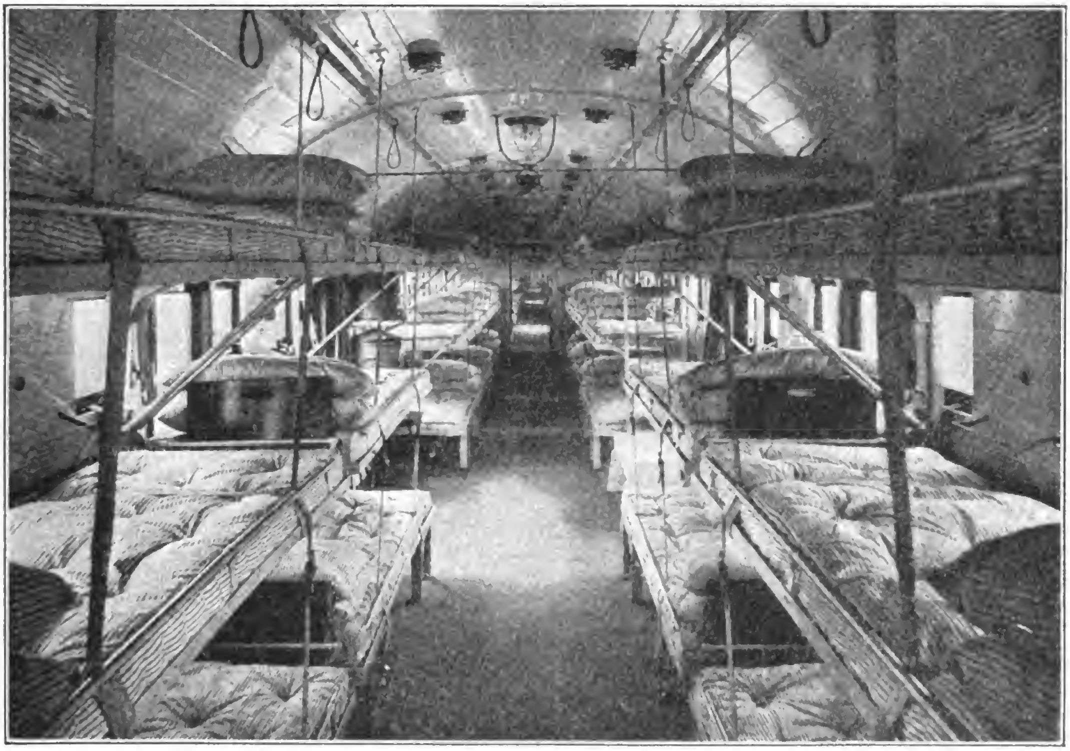
Especially designed to carry two men on each end, with a foot rest on both sides, used either to carry slightly-wounded soldiers or tired officers.

A stretcher designed to meet this situation divided longitudinally in the middle. Each half of the canvas could then be slipped from under the patient, after he had been deposited, in the stretcher, on his bed or operating table; so the transfer took place with no handling and no shock.

The center coupling of the new stretcher

consisted of two fine steel rods, three feet long—one running from each end of the stretcher through canvas loops extending alternately from each side. These rods met in the center loop, and were locked in place by a canvas strap that buttoned over their outer ends in such fashion as absolutely to prevent their slipping out, while each rod checked the other in any tendency to slip inward. The folding handles reduced the minimum length of the stretcher to six feet, making delivery possible to the standard hospital bed, six feet two inches in length.

If the motor ambulance is not to receive our attention, we must admit that the substitution of unusual means of traction is at least of passing scientific interest. Thus, extensive experiments were carried out by the French with a so-called *avion sanitaire* or airplane ambulance, capable of carrying wounded soldiers in absolute safety and comfort, and in the minimum of time for long journeys. The airplane ambulance, no doubt, represented the most ambitious scheme yet tried on any battlefield. Later the dog-drawn ambulance appeared on the Western front. This little two-wheeled vehicle, which is shown in the accompanying illustration, was arranged for carrying two "sitting up" cases or one stretcher case. Attention is drawn to the peculiar, but nevertheless ingenious, shaft arrangement which terminates in a pad resting on the dog's back, and which serves to maintain the vehicle in a level position with the use of but one pair of wheels.



Courtesy of Scientific American.

For the Comfort of the Wounded Fighting Men

Both sides in the World War exerted every effort in caring for the wounded. Here, for instance, is a hospital-train interior for the use of the British army.

HANDLING WOUNDED MEN AS A BULK COMMODITY

Apparatus for getting the wounded man to a place of safety gave the inventor opportunity to work out the problems of transportation on

a small scale. But for the man who preferred to wrestle with the thing wholesale, there remained the question of moving large numbers of sick and wounded men simultaneously from the base hospital to stations still further back. Of course, the good old German way of huddling them into box cars marked "For forty men or six horses" was always available; but the man who was interested in the recovery of the patient would not put up with this. So the designer of railroad equipment was called in to solve the problem, and as a result we had the hospital trains with which all the warring nations—even Germany—were supplied before the war had been going for very long. The hospital ship was an old friend; but the hospital train was a novelty.

Courtesy of Scientific American.

U. S. Ambulance Train No. 59

Which was operated on the London and Northwestern Railway, for the transportation of wounded American soldiers.

To describe one of these trains is to describe them all, so we confine our attention to the latest and best one which we have seen. This was a train designed and built in the shops of the Midland Railway of England for the use of the American Army, and which went into service just before the end.

This train consisted of sixteen cars of one type or another—an infectious-ward car and nine ordinary ward cars, with proper distinctions between those for officers and for privates; a pharmacy car; a staff car and a personnel car in which the doctors and nurses had their quarters; a stores car, and two kitchen cars. In all there were accommodations for 430 staff workers and patients.

As our cut shows, the ward cars were constructed on a vastly more economical plan than that employed in the ordinary sleeping car. There were the same six sections on each side of the car, but instead of but two berths in each section, as in the ordinary practice, there were three; so each car provided space for thirty-six patients. The cots of the middle tier were arranged in such fashion that they could be folded down to form backs for sitting cases in the lower tier. The clearance between tiers, while not exactly generous, seemed ample for all the demands of the situation; and on the whole, the appointments of these "wards" seemed decidedly up to the general hospital average.

A bath tub was an unusual feature of railroad trains, as the layman knew them; but it was obvious that a hospital train had to have one. It was perhaps not so immediately obvious why this feature should be located in the kitchen car; but a moment's reflection upon the exigencies of hot-water supply will clear up this point. It may be pointed out here that one of the fundamental requirements of a good hospital is good water, and plenty of it; so no opportunity to store away the precious fluid above and below and in the out-of-the-way corners of these cars was overlooked. In all, the train carried 2,635 gal-

lons, wholly aside from the engine supply; every car had some, and but two of them carried less than 150 gallons in their tanks. Surely every possible precaution was here taken against drought.

The whole train was painted khaki color, with two large red crosses on white ground at either side of each car. It was vestibuled throughout, and every care had been taken to make possible the keeping clean of the interior—even to rounded corners between floors and walls, in which no dust could find lodgment to defy the efforts of the cleaner. The equipment of all cars—especially those like the pharmacy, designed for special and very technical uses—was admirably worked out in every detail, and on the whole we could not but admire this British contribution to the medical outfitting of the field forces of their American allies.

WAR'S HUMAN SALVAGE

How the Most Desperately Disabled Men Are Restored to a Condition Where They Can Earn a Good Living in Work That Is Worth Doing

ORIGINALLY wartime surgery was carried out only with reference to the immediate military necessities. The wounded man had to be removed from the zone of active fighting, in order to get him out of the way of the active fighters. He had to be treated in the proper way in order to restore him to the fighting lines when possible. But in the many cases where the nature of the wound was such that it was not possible for the man to go back into the lines, the interest of the army surgeon in him was greatly lessened. He was a man and a case, and so got a reasonable share of attention so far as immediate treatment of his injuries was concerned; but at the earliest moment when he could possibly be diagnosed as "cured" or "recovered" he was discharged, and that was the end of his case so far as the army was concerned. He might go home and be a nine-days' hero; his government might eventually get around to the point where it granted financial relief to him and others like him; but so far as scientific care and attention was concerned, his case was finished with his discharge—and his discharge ordinarily would come along almost as soon as he was able to walk.

WHAT TO DO WITH A WOUNDED SOLDIER?

It must be confessed that correction of this point of view proceeded from Germany. It is not to be inferred from this that the German doctors or the German authorities had any particular consideration for the wounded soldier. If the interests of the man alone had been concerned, he would doubtless have been allowed, on the east of the Rhine as well as on the west, to drift into pencil peddling or some other form of genteel begging. But the German, with his characteristic thoroughness and the superficial efficiency that he loves so much, realized that no matter what the war cripple did to support himself, the industrial and economic organization of the state must in the last analysis support him. He must have food and shelter and clothing; and these must be provided from the common fund from which food and shelter and clothing for all the community are drawn. So it is good economy to provide the cripple with the work which he can do most effectively, in order to get out of him the maximum return. If anybody else takes up this same idea, he is at liberty to put it on a more altruistic basis—to say that he gives the cripple work he can do for the cripple's sake, in order to make him self-respecting and independent. But let there be no mistake about the reason why the German Staff took up the work of reconstruction and reëducation of the war's wounded; this was done purely for selfish motives, and without any thought of the good of the men involved. Even the Allies, in following this lead, did not lose sight of the economic advantages.

Whatever the motives, however, reconstruction and reëducation call for the same scientific background of preparation. If you are going to make a deliberate effort to give to a physically sub-normal man work for which he is best qualified, you must devote a lot of careful attention to finding what that work is. If it is an object to make the cripple's work of as advanced a nature as possible—if we want every cripple to produce the very best that it is possible for him to produce—we have got to work on the man as well as the task. We must select a task for which the man can be fitted; but we must then proceed to fit him for that task.

So where the old system is to discharge the man as soon as he is able to remove himself, under his own power, from the sight of the hospital attendants, the new idea involves keeping him under the care of skilled doctors and physical trainers until he is in the best shape which it is possible for him to attain. It must be a prime object to restore as completely as may be the natural functions of all parts of the body. The man who comes away from the hospital with a stiff leg, or an arm that is all there yet lacks the power of a normal arm, has not had the best treatment which it was possible to give him. Heat, light, electricity, mechanical therapy, all have their places in this organized effort to make the most out of the human wrecks of war.

THE MECHANICS OF CONVALESCENCE

Mechanical treatment is usually an after treatment, though it may sometimes begin before the injured bone or joint is entirely healed. It is based on the idea that the lack of use which ordinarily accompanies convalescence leads to lack of nutrition and to atrophy of the part; it aims therefore at improvement of nutrition through maintenance of function. The means employed are massage and gymnastics. Various kinds of machinery are used which have different methods of maintaining local movement of the affected part, but always the force is adjustable and the direction defined with care. The movements are of three sorts: active, in which the patient takes part; passive, in which he is acted upon without let or hindrance on his own part; resistant, in which the machine opposes a regulated resistance to movements engineered by the patient. The subject stands, sits or lies, according to his condition and the nature of the treatment required. Among the apparatus used is machinery for bending, stretching or rotating various joints which may be stiffened from trench-rheumatism, from actual effects of the wound, or from long confinement in one position during setting; machinery for expansion of the lungs, permitting better oxidation of the blood after a chest wound; machinery for producing mechanically such effects as those of percussion, friction, kneading or vibration. These are also attained by hand massage.

Among specific machines, mention may be made of one which serves to exercise the ankle and lower calf. The foot, which is attached to a turn-table, lifts a weight as it is turned from side to side. An indicator moving over a scale next to the turn-table indicates the effort expended.

A similar device is employed for strengthening the weakened wrist. The hand is strapped to a turn-table, and when moved from side to side raises a two-pound weight in direct proportion to the power expended. A dial serves to indicate the effort, so that the strength of the weakened wrist can be constantly measured.

For curing flat feet and stiff legs the devices employed are of the simplest. In the former case the patient walks on two boards slanting away from each other. In the latter case he walks with one foot on a steadily rising platform and with the other on a horizontal platform, thus causing the first leg to be bent more and more.

Ankles may be strengthened by using another device, which causes the ankle to be worked from side to side. A similar machine strengthens the fingers and wrist. If the patient is unable to turn the wheel which operates this device, a nurse does it for him.

Stiffened hands are exercised in various ways. Some patients are asked to operate a dial arrangement controlled by a knob; as this is turned the rotations made are recorded on the dial. Other devices for the same purpose involve the raising of weights; as the fingers are raised and lowered these weights, connected through pulleys to the gloves worn by the patients, are moved proportionately.

German Soldier With Artificial Arm

Other aids employed to hasten the cure of the wounded soldier include electric-light baths, currents of hot air, and actual application of the electric current to the muscles in attacking the tendency to muscular or nervous paralysis which so often follows a wound. Such methods as this are frequently of great value in treating men who have not suffered an actual physical wound, but have succumbed to the extraordinary nervous stresses of modern warfare.

These methods, however, have attained their limit when the patient has regained full and normal use of all the muscles which he possesses. But of course there are many men who come from the operating table with arms or legs or hands or feet or other members lacking. These patients require the treatment outlined above, to get into good condition whatever members they may have; but in their cases this is not enough. They must be given a substitute for the lost member, and taught to use it with effect. Perhaps the very greatest advances made by invention in connection with the late conflict have been scored right here. Particularly in the case of artificial hands and arms have the results achieved bordered upon the miraculous.

THE MAN WHO LACKS A LIMB

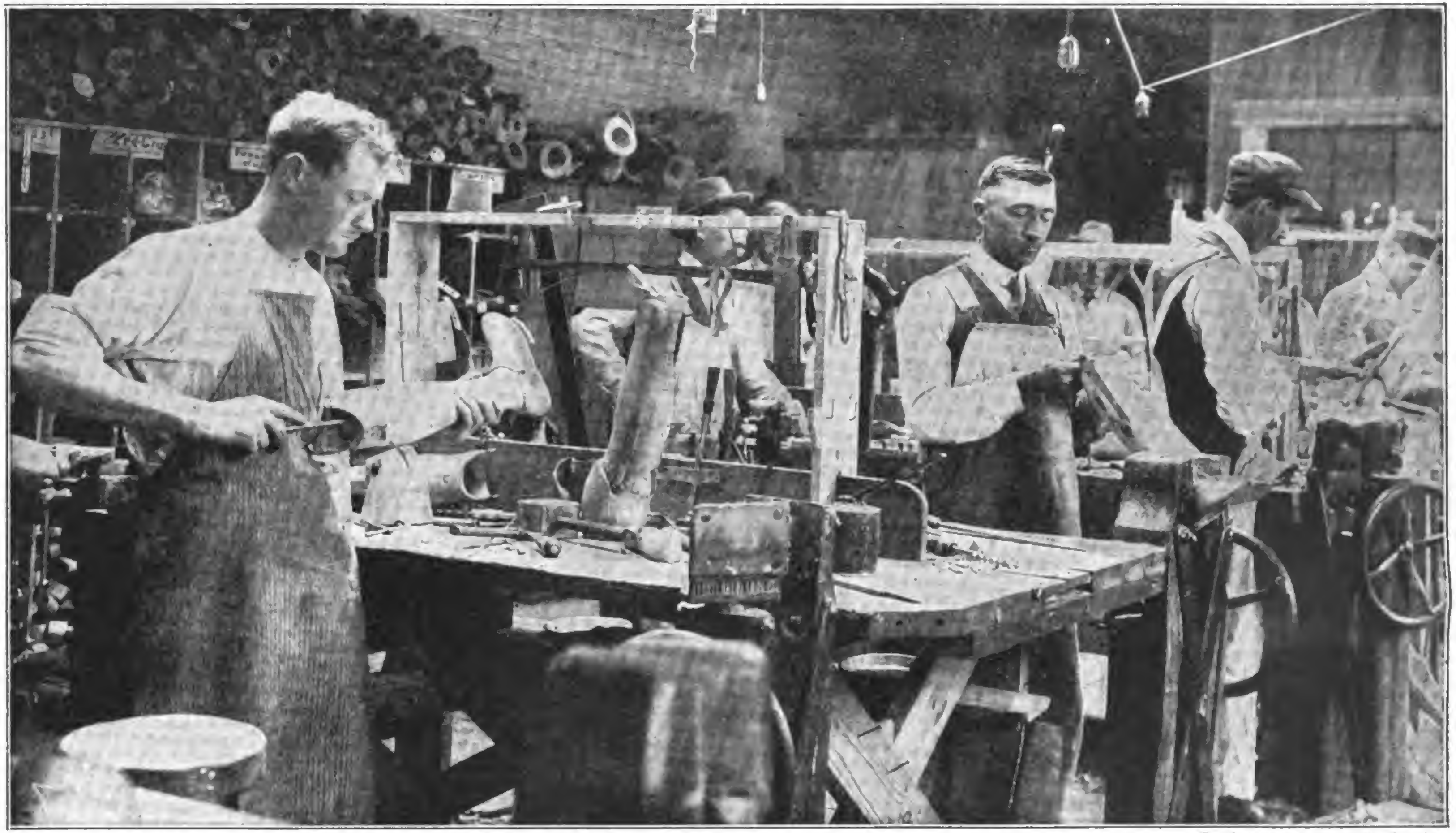
The industrial efficiency of a man who loses an arm is at once so reduced that he sinks into or below the class of unskilled labor. Men who can earn their living with their heads are of course not thus affected; a man with brains and will power and a reasonably adequate training will not be kept down by any disability. But those who are forced to depend upon their two hands to make their way in the world know that with only one of them they cannot go far. A job as doorman or caretaker or errand boy is about all that such a man can hope for, unless he can be provided with a practical working substitute for his lost arm, and trained to use it.

The old-fashioned idea of an artificial arm was merely a piece of wood or leather in the shape of a hand and arm. This may look like an arm, but it doesn't do the work of one. It is satisfactory enough to the clerk who can do his work with one hand and wishes something to conceal his deformity; but for the man who has to grasp a tool it is useless. The successful arm for the manual worker is the one based on the idea that it is not an imitation arm which is wanted, but rather a tool-holder. It will not remotely resemble an arm in appearance; but the proportion of the work of a hand and arm that it will do is amazing.

The mechanical tool-holder, or as the surgeons call it, the working prosthesis, should be designed to do the work of the less active, or helping hand—in right-handed persons the left one. If it is the right hand that is gone, the left takes its place as the active hand, being in turn supplanted, in its old function of supporting the tool, by the artificial member. We do not ordinarily realize the extent to which one hand supplies the power for our actions, leaving the other no function save that of support. But when we consider the case of the one-armed golfer who plays on equal terms with a two-armed opponent, the facts must be clear.

For those *amputés* who have preserved the elbow joint, an American firm has developed an artificial arm with which are possible a large variety of movements. Flexions of the wrist, opening and rotation of the "hand," placing the "fingers" in certain positions and holding them firmly there, are all accomplished with no intervention of the other hand aside from the engaging and disengaging of a catch. A German firm has perfected a system attached rigidly to the shoulder whereby movements based upon the humerus, collarbone, or shoulder-blade are transmitted to the stump of the forearm. The hook terminating this artificial arm can be subjected to heavy loads without in the least straining the enfeebled muscles of the wounded man.

It is the French, however, who have given most attention to artificial hands; and they have placed the entire technique of artificial limb supply upon a standardized scientific basis. At the laboratory of military prosthesis established in Paris careful determinations are made of the muscular and nervous conditions in and around the damaged limb. In accordance with these observations individual prescriptions are made and carried out with a degree of skill which could not by any possibility be approached in times of peace, with the negligible number of cases which then arises.



© *International Film Service.*

The Greatest Plant in the World for the Manufacture of Artificial Limbs

A workroom in the factory of the Hanger Artificial Limb Company, Washington, D. C. Many of the workmen are themselves cripples, wearing the artificial limbs turned out by the factory.

FRENCH ARTIFICIAL ARMS

The ordinary type of arm supplied to laborers and mechanics consists of a thin steel bar terminating in a sort of crab-foot attachment. The base of this is a steel cup with leather backing. The latter is either hard and molded to the stump-end, or soft and laced about it, according to the length and shape of the stump. The steel and leather cup is firmly strapped to the shoulder in such a way as to be governed by a band passing about the chest and under the opposite arm-pit. There is at the point where the steel bar enters this cup a most ingenious joint combining the ball and socket and the screw principles, while in addition the bar carries an ordinary hinge joint. Both these joints are supplied with stops which can be set either to hold them rigid in any desired position or to leave them free to operate, checking them at a given point. These must be set by the other (natural) hand. There is no independent motion of the crab-foot hand; it is merely set by the natural hand to grip the tool, which is released in the same way when the operation is completed. The motive power is of course supplied by the muscles of the upper arm, the shoulder and the chest; or in extreme cases by swaying of the body. It is most extraordinary how skillful the *amputés* become in the manipulation of this arm. It is interesting to note, also, that when he has finished his day's task, the workman unscrews his working hand and replaces it with a more elegant "dress hand" for public exhibition on the streets.

For the clerical or professional worker and the skilled artisan there is made a much more elaborate hand. It is of nickeled copper, with separate fingers, and even simulated finger nails. The metal shell of the palm is made in two pieces, front and back, leaving, when fitted together, holes from which project the fingers. Each of these is in one piece and therefore rigid, but gracefully curved. Each is hinged on to a common axis inside the shell of the palm, and held in closed position by a spring. Levers of steel passing over a cog-wheel control these hinges, and at this cog-wheel terminates a flexible steel cable passing in a leather tube under the arms and about the chest.

The motive power for the operations of this hand is furnished by expansions and contractions of the chest, which affect the flexible cable. The mechanical arrangements of the hand are such that the fingers imitate in their workings the motions of those of a natural hand; the proprietor does not have to concern himself with the details at all. He merely generates the power and the machinery does the rest. He is able to grasp all manner of objects, either in the hand or between two fingers; even the handling of a match or a pin is not at all beyond him.

The general principles governing this important surgical procedure are clear. The arm involves no great difficulty; it is the hand itself that presents the critical problem. There must be some means of grasping—a spring, a set-screw operated by the good hand, etc. The arm and "hand," as just brought out, are modeled according to the work to be done and the tool to be grasped; in its turn, this tool is designed with special reference to the fact that it is to be used by a man with a metal jaw in place of a hand, a man well able to hold on, but not to seize and let go with ease. Thus special arms and hands are furnished in France for laborers, vine growers, postmen, chair caners, leather cutters, general mechanics, packers, carpenters, jewelers, drivers of animals, motor drivers, machinists, stone-cutters, printers. Men of these trades are frequently trained to return to them, with complete success; men of other trades which are believed to call for too delicate work with the secondary hand are with equal success initiated into one of the trades named, in which that hand is called upon for little more than support of the tool.

The efficiency of any working arm depends largely upon the length of the stump. If the elbow joint and the power to move it are conserved, the hand will of course have more power and more extensive limits of motion. If the elbow joint is a mechanical one, it must be fixed in each position by jam-nut, lever or screw, with consequent loss of time, mobility and strength. An effective working arm is, in general, out of the question if less than a third of the upper arm remains to impart motion to the attached member. It may be here pointed out that the preparation of the stump to receive the working arm is a very delicate matter, involving frequently

strengthening exercises of a very special nature, and calling for the nicest judgment as to just where the amputation can most profitably be made.

LEARNING TO USE AN IRON HAND

Once upon a time it was customary to fit out a man with a peg leg or an imitation hand, and turn him loose to find out as best he could how to use the new member. This procedure has also gone overboard. The man who is fitted out with an artificial hand or leg goes to a special school whose first task is to make him independent of others and to reawaken in him the confidence he has lost. At the hospital proper, during his convalescence, he has been induced to while away his time with manual work of the most varied description, to prevent him from brooding over his injury and his future. The school takes up where the hospital left off, and by the time the patient has fully recovered his physical tone through exercise, he has learned through supervised practice to do without outside help in the ordinary conduct of his daily life. In the long run he has got to wash and dress, eat and drink, without outside aid. The sooner he learns to do these things the better, not only for their own sake, but because when he finds that he can do them he attacks with greater will the more difficult matter of learning to work.

Keen analysis and judgment is required on the part of those in charge when this point is reached. Can the patient most profitably return to his old work, or will he better take up another line? Every factor has here to be considered—the nature of his injuries and the nature of the trade proposed for him must be regarded from every viewpoint. If he has lost a leg or two, the question of whether the trade is a standing one or for the most part a sitting one decides the issue and he will become a typist, a telegrapher, an automatic machine operator, etc.; otherwise a great many things have to be given due weight, and the fair answer arrived at. Once this decision has been reached, it is only necessary to put the man at work under competent instruction. His teacher is, whenever possible, a sufferer from the same infirmity that afflicts the pupil. The blind teach the blind, the armless the armless, the legless the legless; and it is found that the student follows the teacher wherever he leads, under these conditions, with much more earnestness and far greater success. In general principles, of course, there is nothing especially new about the actual industrial training of the war cripple; so we need have little to say about it.

A word must be said about vocational therapy, however. Perhaps this should go into the chapter in which is described the actual treatment of the wounded, before they have graduated into the class where they receive industrial training; but on the ground of its industrial bearings we mention it here instead. It is based upon the good old theory that Satan finds work for idle hands, and that if you give a man something to do, he will be better off. But you can't fool the average citizen; if you tell him to count the squares in the wall-paper, or to twiddle his thumbs, or to do something else which may not be quite so extreme as these things but which possesses no greater actual practical value, he will not be interested. Consequently, when a man in the hospital refuses to show any preference for living over dying, the first thing to try is a little gentle training in weaving or some other work in which he is obviously making something of value. It is found that in by far the vast majority of cases this is a most effective measure against the dull, drab hours of convalescence.

WHAT IT MEANS FOR THE YEARS TO COME

The immediate interest of scientific prosthesis and reëducation is, of course, in connection with the war. But in the nature of things, this can be but temporary; there will come a day when the cripples of the World War are no longer present. The apostles of the new science point out that their work will outlive the immediate necessity which has given rise to it. There are certain always to be a quantity of cripples as the result of accident. These cripples are not sufficiently numerous to make it possible, on their behalf alone, to go to the vast expense of initiating such a system as the one described; but with the system established as a result of the war, we can easily afford to maintain it in the interests of the victims of ordinary accident.

Indeed, we cannot on any account afford *not* to maintain it.

Another field which we may expect to be permanently occupied is that held by the man who examines the war cripple and prescribes for him the employment which he will best be able to follow. Is it trespassing too much upon the sacred rights of the individual to look forward to a day when the privilege of wasting his efforts in work for which he is not fitted will be denied him? It is within the bounds of reason to predict that the present advances in reëducation are but the forerunners of still greater strides to come, strides which will at least make it possible for us to direct all those who are physically or mentally sub-normal into the callings for which they are least disqualified, and which at their highest development would enable expert examiners to present to every human being a list of half a dozen occupations in which his success would be a maximum. Under such a dispensation we should be done with the forced conversion of potentially excellent blacksmiths into doctors and lawyers and engineers, and with the loss of super-mathematical intellects through condemning their possessors to work in a coal mine.

THE CLIMAX OF RESTORATION

How Badly Mutilated Soldiers Are Given the Appearance of Sound and Normal Men

WHEN a man has been "amputated," as the French rather quaintly express it, the very first problem which must be dealt with is that of supplying him with whatever he may need in the way of artificial hands and arms. If he cannot earn his living, nothing else matters very much. But if he can be equipped to resume his place in the industrial community, a lot of things matter. He wants then to look as much like a normal man as possible, he wants to walk as much like a normal man as possible, he wants in every respect to be as normal as science and skill can make him. So the service which has supplied him with new hands must stand ready to supplement these with various other things that he may need.

Of course it is a figure of speech to assume that the man who needs new hands and the man who requires the replacement of some other portion of his anatomy are always the same man. But whether they are the same man or not, their cases call for the same attention. And as a matter of fact, since the perfection of the Carrel treatment, amputations due to the infection of a wound that would otherwise have been easy enough to treat are very rare. Arms and legs now have to be sacrificed, in general, only when their owner has been so close to the striking point of a shell as practically to be blown up by the explosion. This is why, in picture and in text, we see and read so much of men who have lost two or three or even four limbs; any smash-up which can now damage a soldier to the extent of making one amputation necessary is pretty apt to have made a total wreck of him and to call for amputation on a wholesale scale. The man who today loses an arm in battle may consider himself fortunate if he loses nothing else.

CONCERNING WOODEN LEGS

The artificial leg has gone as far forward during the past few years as has the artificial arm; but with it the advance has been in the way of simulating nature. The peg leg is today an anachronism; the man with a wooden support looks in all respects like his sound brother, and acts surprisingly like him too. The wearer of a single wooden leg can dance and run and box and walk with anybody who is not a professional in the line in question; and even a man with two artificial legs, one attached above the knee and one below, has done a hundred yards in fifteen seconds.

It is the practice to work the willow up

into rough legs and to put these in stock in sizes on a basis similar to the method of stocking boots. Several lengths of legs, allowing for variations above and below the knee, all have their respective size numbers, and six sizes of feet are also accounted for so that the artificial foot shall be a reasonably close match for the one that Nature has attached to the other leg.

When a man is sent by the medical officer to be fitted for a limb, his measurements are taken and the stock limb most nearly approximating his measurements is tried on. The top of the artificial leg is hollowed with special tools made for that purpose, and in above-knee amputations the stump leg is fitted into the socket until the patient bears his weight on the pelvic bone, virtually sitting down on the leg and walking. In the case of below-knee amputations the weight is carried, when

© International Film Service.

A French Soldier Wearing a Mask to Cover a Shell-Torn Face

possible, partially on the end of the stump and partially on the bones of the knee.

After the man's stump has been fitted into the rough leg, the patient wears his new limb around the hospital until it has become quite comfortable, trimming being done on the inside to remove unevennesses as suggested by the patient. Then, too, a man wearing one artificial leg places such a great strain on the other, especially in the early stages, that a special shoe is required. The patients are measured and fitted with boots designed to prevent weakness developing in the one good foot remaining. Every upper is fitted.

NEW FACES FOR SHELL-TORN SOLDIERS

Aside from the provision for replacing lost limbs, a great deal of interesting work has been done in the restoration of the one part of the human anatomy whose injury is most visible and most offensive to the eye of the beholder—the face. It is truly appalling what ruin may be wrought here by a shell. Not only are eyes torn out with much of the adjoining flesh and bone, leaving yawning abysses in the face, but the entire jaw may be shot away without fatal results; and a man thus wounded must be restored to approximately normal appearance so that he can associate with human beings with comfort to himself and to others.

Much of the remarkable advance of surgery has been in this direction, and sculptors have joined hands with doctors in working out the reconstruction of shattered faces. Often when the jaw is badly smashed up and the nose completely torn away, while the rest of the face is mutilated apparently beyond all hope, these skilled specialists come to the rescue and perform the miracle of making the face almost as good as new. Masks of copper are modeled to the proper contour, as indicated by old photographs, and after being carefully adjusted in place are painted the same color as the patient's face.

The use of ambrine in the treatment of burns, though in a way a matter more strictly of actual treatment than of restoration, may be mentioned here since one of its chief effects is the reduction of the permanent scar. It will be understood that the process of burning flesh is, chemically speaking, quite identical with that of burning anything else. Given sufficient heat and sufficient oxygen, anything that is not already completely oxidized will burn; and flesh is no exception to this general rule. The heat is supplied by the burning agency—flame or explosion or what not—and the oxygen comes from the air.

AMBRINE AND THE TREATMENT OF BURNS

Now everybody who has ever suffered a severe burn will recall that while the process of burning was far from comfortable, the really acute pain and suffering was a bit delayed. Not until after the removal of the burning agency from the wound, and the consequent full exposure of the latter to the oxygen of the air, is the process of burning carried to its full and extremely painful conclusion. In other words, after the first rapid oxidation of the flesh at comparatively high temperature—which cannot be prevented if burning is to occur at all—there ensues a slow oxidation at comparatively low temperature—which could be prevented if there were some means of excluding the oxygen. This secondary burning may be likened to the long slow smoldering of a bonfire which is dying out for want of fresh fuel.

The first rapid oxidation is serious enough, surgically speaking, for it involves breaking down of the tissue, and especially of the skin, in a way which nature is frequently powerless to repair completely. But the slow secondary burning is even worse, for it involves such pain that treatment becomes difficult, and it carries the destruction deeper than it otherwise would go. The problem in treating burns has always been to find some means of arresting this secondary burning; and this, of course, reduces at once to the exclusion of the air. But here a great difficulty is met, for the ordinary bandage does not exclude air, unless it is put on so tight as to cause unbearable pain upon the burned surface.

There is a wide variety of soothing applications for "taking the fire out" of the burn. Thick oily substances tend to form a layer over the wound, impervious to air and hence insulating the flesh from oxygen. This eliminates the pressure of a tight bandage; but for that very reason it does not afford complete insulation.

A development of French war surgery has been the ambrine treatment for burns. Ambrine is an artificially compounded substance, very similar in general nature to paraffine. Its melting point is sufficiently low so that it can be applied to a fresh burn in liquid form, and sufficiently high so that it will in due course thereafter solidify. It is free from chemical action upon the burned flesh—the objection which has heretofore prevented the use of waxes, etc., in this way; and it molds itself to the surface of the burn with great closeness, so that a minimum of air is caught and confined beneath it. The treatment therefore effects a better insulation of the burn from air than has ever before been possible, while at the same time protecting it from physical contacts of all sorts. Consequently it leads to more rapid healing, with less extension of the damage, than has ever before been attainable. The result is that skin grafting, when necessary, is begun earlier, with less concern as to the readiness of the wound to take it, and carried out more effectively; that the whole course of treatment involves far less pain; and that scars are greatly reduced in area and malignancy.

GLASS EYES THAT DEFY DETECTION

Another fruitful field for the surgeon who turns his thoughts toward the external restoration of his patients has to do with the provision of artificial eyes and the appurtenances thereof. The high velocities and high explosiveness of the present-day projectiles not only result in facial wounds of the most horrible appearance, whose repair seems almost hopeless, but frequently lead to injuries of such depth and serious character that in no previous state of surgery would their repair have been attempted. In particular, soldiers return from the line of fire not merely with an eye shot out, but with the entire lid and eye-socket destroyed, and the absence of these foundations has often made the insertion of an artificial eye seemingly impossible. But a French oculist, Henri Einius, made this

© International Film Service.

An Artist at Work Painting the Mask of a Soldier to Make it Life-Like

possible even when the eyelid is entirely missing.

In its essential features the apparatus consists of an artificial eye, equipped with a lid of any convenient plastic material—paraffine or molding paste, colored to match the subject's complexion. This eye is furnished also with lashes, to give it to the fullest possible extent the appearance of a natural eye. It derives its support from fine metal wires attached to eyeglass or spectacles, so adjusted that when the latter is placed upon the nose, the artificial eye falls accurately into its cavity. The eye may easily be separated from these attachments for cleaning.

In case it is desired to have a somewhat stronger pressure upon the ocular cavity, the supporting wires may be replaced by light springs of toric or other shape; and in pursuit of a similar goal there may be inserted, behind the artificial lids, a washer of elastic gum to prevent the entrance of dust.

KEEPING THE ARMY FIT

The Wide Field of Sanitation and Disease Prevention Over Which the Activities of the Medical Service Now Extend

IN the days when contagious disease was looked upon as a scourge from God or a visitation from the devil, it would hardly have been considered fair to hold the doctor responsible for the health of an army. It is, however, surprising to note to what a late date this viewpoint has, at least implicitly, been held—and by the same token, to what a degree the course of wars has been governed by epidemic.

Campaigns which by all military prognostication should have succeeded have failed because cholera, plague, typhoid, typhus, smallpox, malaria, dysentery and yellow fever have surpassed the powers of shot and shell to destroy. Thus the returns show that in the brief war with Spain, our dead from sickness—mainly typhoid and yellow fever, as will be remembered—were seven times more numerous than the direct casualties of fighting. In the Balkan War which served as preliminary to the vast conflict of all nations, the Bulgarian campaign broke down largely because of epidemics. There were 30,000 cases of cholera in one day!

Indeed, the first respectable showing in the way of army sanitation was that of the Japanese in 1904-05. Throughout their war with Russia the little Asiatics suffered but the most insignificant losses from disease of all kinds; and their record made it very clear that thereafter an outbreak of any of the better understood diseases in a civilized army could only be looked upon as an utter disgrace.

PREVENTING INFECTION

The agency through which the army surgeon meets and defeats disease is of course inoculation. He makes a better showing than the surgeon in civil life only because of his greater power to learn correctly all pertinent facts, and his greater authority to deal with his patients. Given the researches of Pasteur and his successors, plus the technique of sanitary engineering as developed in Cuba, Panama and the Philippines by the American military, and organized immunity from disease is reduced to very simple terms. This is amply illustrated by the record of the British Army in the World War. In the first six months, only 421 cases of typhoid had occurred on all the fronts and in all home camps; and of these cases 305 were in men who had not been inoculated within two years. Among those who had been inoculated there had been but a single death, and this was of a man who had received only one inoculation in place of the regular two. This record stands out in sharp contrast with that of the British in the Boer War, where they had 58,000 cases, of which 8,000 terminated fatally. The difference was simply a matter of inoculation.

This dates back to the fundamental dis-

covery of Pasteur that the inoculation of a subject with attenuated toxins produced by artificially cultivated pathogenic bacteria may lead to the formation in his system of anti-toxins immunizing him against the attacks of these same toxins. Thus a vaccine is a virus endowed with feeble activities, harmless to the individual in whom it is injected, but capable of conferring immunity upon him. A vaccine differs from a serum, in that it merely stimulates the human organism to react against the activities of a certain class of bacteria, and does not contain wholly formed anti-toxins, which have been artificially developed in an animal, as is the case with a true serum.

The first to develop the idea of vaccinating against typhoid fever, the greatest scourge of armies, were two French physicians, Chantemesse and Widal, who carried on a series of experiments from 1888 to 1892. They inoculated with bacilli that had been killed by heat, but unfortunately they employed high temperatures to 120°C. (248°F.). As the Anti-typhoid Committee of London stated as early as 1902, the heating of a sterilized culture to a temperature above 65° serves to weaken considerably the curative properties of a vaccine thus obtained. The use of bacilli living, but attenuated in virulence, was suggested even earlier by Ferran, and then Haffkine, as a protection against cholera and the plague. Pfeiffer, in Germany, showed the possibilities of employing dead microbes; and in 1896 Almroth Wright, in England, as a result of previous work, proposed as a typhoid vaccine a microbe culture, heated to 56° or 58°C. (*i.e.,* 133°F.). About the same time Aldo Castellani, in Italy, professor in the University of Naples, recommended the use of a vaccine containing living bacilli, but attenuated by exposure to a temperature of only 50°C. (122°F.). All of these attempts had various defects; but experiment continued. Wassermann attempted in 1904 to kill the microbes by the use of chloroform, and three years later this method was used for the manufacture of anti-typhoid vaccine by surgeons in the British Army. In France, M. Vincent, professor in the military school of the Val-de-Grace, made a series of comparative tests on various solvents for the bacteria. He finally discarded all containing antiseptics, and successfully prepared several kinds of vaccines known as polyvalents.

The anti-typhoid vaccine of Vincent was straightway developed and extensively used in France, especially in the army. It was employed from the beginning of the Moroccan campaign (1912), and served to keep the French troops in excellent hygienic condition. It was also used by Greece during the Balkan wars, and by Italy in its Libyan expedition. It was the Vincent vaccine which the Health Service adopted when the law of 1914 rendered anti-typhoid vaccination obligatory in the French Army.

THE MANUFACTURE OF VACCINE

The technique followed in the anti-typhoid laboratory of the French Army is typical of the preparation of all such substances in all countries, and is of great interest in showing to what an extent this is a regular manufacturing proposition. The first process is placing the bacilli on the gelatine which has been run into shallow dishes, previously sterilized in the autoclave. The operator by means of a pipette, which is connected with his mouth by a rubber tube, takes the desired quantity of the virus from tubes placed on the table before which he is seated, and introduces it into a culture flask, which he stops with a tampon of cotton that has been passed through the flame of a gas jet. Ten varieties of typhoid bacilli, indigenous and exotic, are used in the preparation of the anti-typhoid vaccines. Next the flasks containing the bacilli are carried to an incubator maintained at 38°C. (100°F.) and are left there for 19 hours; after which a sterilized medium is added to this microbe culture, and then pure ether is added to the emulsion of typhoid bacilli thus produced. The mixture after being shaken for some seconds, is put aside to stand for five hours. The lower portion, which is drawn off, contains all the bacilli and soluble immunizing substances. On account of its lightness, the ether rises to the top of the drawn-off liquid which, with the addition of a certain quantity of salt water, constitutes the definite vaccine.

The number of bacteria contained in each liter is now carefully determined and sterility verified. When the flasks containing the vaccine have been thus tested, a siphon specially

devised by Professor Vincent is employed for the aseptic distribution of the vaccine in glass capsules of 2, 5, 10, or 20 cubic centimeters. After being filled, these are sealed by blowpipe flame, and labels bearing the date of preparation are pasted on the glass. These glass capsules are kept in refrigerators, and maintained under such conditions that their active properties persist for three months.

Among the more important and useful devices are the heat sterilizers and the apparatus employed for the distribution of the vaccine in the glass capsules, both of them contrived and used according to the direction of Professor Vincent. In the sterilizers used for all the glassware, the gases of combustion pass into the heat chamber through iron tubes arranged like organ pipes. The heat circulates from bottom to top, passing through other pipes arranged inversely to the former. In this heating apparatus, the complete sterilization of numerous tubes, bottles, flasks, etc., takes place in 20 minutes, for the heat diffuses uniformly throughout the chamber, in place of being simply transmitted by a plate of sheet iron, and distributed unequally, as in ordinary laboratory ovens.

The special apparatus for the solution process is used also for the distribution of the vaccine into the capsules. It consists of a square wooden table resting on four metallic feet, and surmounted by a cylindrical standard in the rear, designed to receive the flask containing the liquid to be transferred. The rubber stopper which closes this receiver is pierced by two holes; in the first is a straight glass tube through which there passes air compressed by a foot bellows. The second orifice, arranged laterally, affords passage to a glass siphon through which the liquid passes. A glass bell arrangement serves as a cap to the flask or capsule so as to prevent contamination by germs in the atmosphere in the course of the operations.

Independently of the anti-typhoid vaccines, there are prepared also under the direction of Professor Vincent, and according to the same technique, the anti-paratyphoid vaccines A and B, and the triple vaccines for anti-typhoid and anti-paratyphoid use, or vaccines T A B, intended to combat the two paratyphoid affections that are quite different from typhoid fever, although presenting analogous symptoms. A true and correct diagnosis for these maladies is secured by the appearance of the cultures obtained from the blood of the patient.

Here then are our little glass tubes, sealed and labeled, which straightway are issued to the surgeons for the inoculation of the troops. The surgeon's assistant, after having sterilized by boiling the glass hypodermic syringe, the needle, and the nippers which serve to break off the end of the flask containing the vaccine, disinfects with tincture of iodine the region of inoculation, which is often the shoulder. Then the surgeon inserts his hypodermic needle, and slowly and steadily injects the vaccine under the skin, a little below the shoulder blade. Three or four successive inoculations of the vaccine T A B, at weekly intervals, confer absolute immunity. However, in the army zone, or in case of emergency, two vaccinations suffice for checking impending epidemics.

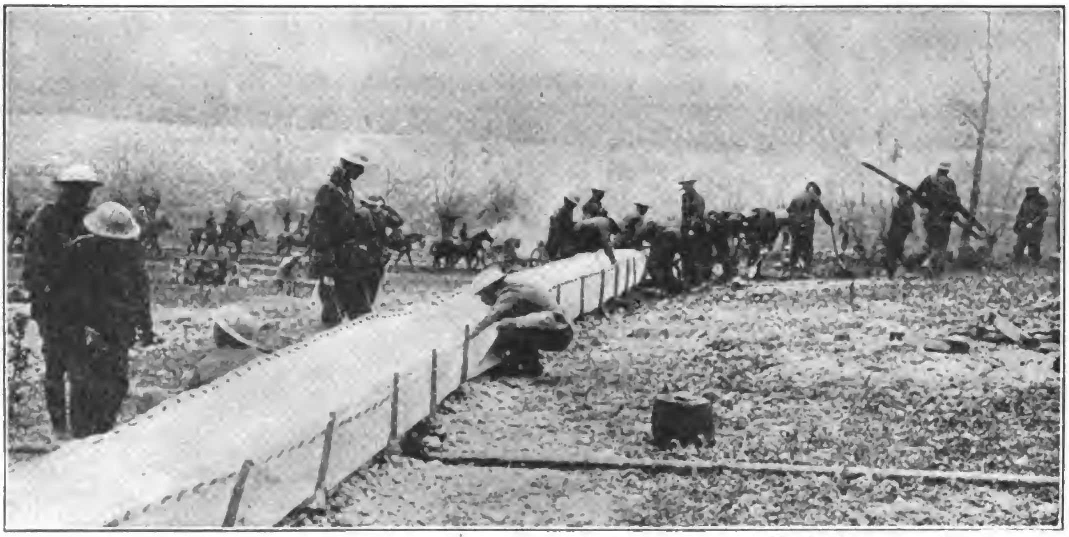
THE PROBLEMS OF WATER SUPPLY

The problem of immunizing the army against any other disease whose germ has been isolated, or at least whose manner of contagion is known, is substantially the same. But it must not be imagined that the efforts of the surgeon and doctor to keep the army fit end here. This is not enough to make the men immune; they must be protected from exposure, so far as possible, in order that too great demands be not made on the immunizing agents. In olden times, when the army lived off the country, this would have involved a very strict supervision of all food—and would, in fact, have been quite out of the question. Today, when an army carries its food with it, the matter is far simpler; for there is but one important agent of possible infection—the water, which our armies, like the fighters of centuries ago, still expect to find on the spot.

Although great quantities are needed, it would not ordinarily be so difficult, as compared with some other descriptions of supplies, to provide a sufficiency. The circumstances developed in France during the great struggle were, however, decidedly exceptional. On account of the crowding of great bodies of men into limited areas, where they carried on

existence under primitive conditions, it was exceedingly difficult to prevent the contamination of streams and wells which would under ordinary circumstances be relied upon. Then again, the enormous pits excavated by the great high-explosive shells collected water that soon became stagnant, and contaminated the surrounding supplies; and to make matters still worse the Germans systematically poisoned and infected every source of water supply within their reach.

All of these things made the work of supplying potable water to the armies a difficult task, particularly as it was one that had to be kept up continuously without intermission, no matter how great or how rapid the changes in position might be. Chemists and bacteriologists were constantly busy examining and testing every possible source of water, and these tests had to be repeated day by day, and even several times a day, to guard against infection. In many districts river water was used almost exclusively, as in the valley of the Somme; and in such cases the water was thoroughly sterilized and filtered before the troops were permitted to make use of it. On the rivers purifying plants were placed in barges, while in other regions portable sterilization apparatus was carried on railways and motor trucks, which moved from place to place as required. In considerable portions of the territory in which the British were operating, driven wells were extensively used, and these wells had to be put down from 150 to 200 feet to penetrate the underlying chalk formation and reach the water-collecting levels. In the Verdun region most of the water was obtained from wells dug by hand, although many driven wells were also sunk. The hand-dug wells were about four feet in diameter, and sometimes were excavated to a depth of 65 feet; but in all cases the water was carefully examined and purified wherever there was the slightest suspicion of infection.



© Underwood and Underwood.

A Canvas Pipe Line

Here is the way an army builds a temporary pipe line in order to supply water to the troops.

Wells were everywhere cleaned out and disinfected, and pumping plants installed; and where specially large supplies were required at any particular place, as at training and rest camps and at base hospital centers, quite elaborate water works were installed, with pipe lines several miles in length for distributing the water, with reservoirs, hydrants and supply tanks at convenient locations. Along the main roads were erected tanks to supply the portable kitchens and also the motor transport trucks. For advanced stations water was brought up by large motor truck tanks, which delivered to tanks as near the front lines as possible. From these tanks water was taken into the trenches in small kegs. Watering

animals presents a special problem, for where there are large numbers it is not possible to allow them to drink directly from a river as their tramping would soon muddy the stream for a long distance; so the water is pumped up into special tanks, from which it can be drawn into troughs as required. For pumping, every kind of apparatus was employed according to circumstances. Where small quantities are required a simple hand pump is all that is necessary; while for the larger establishments a regular steam plant is installed. Often for filling motor truck tanks a pump is carried in the truck, in which case it is operated by the power of the truck engine, and this makes a movable outfit of great convenience.

The importance of a supply of pure water may be appreciated if we look back over the records of hygiene in the armies of recent wars, and note the terrible losses resulting from enteric diseases, and compare them with the practical absence of this trouble in the present war where vastly greater numbers of men were concerned. Typhoid fever is always a much dreaded disease wherever great numbers of human beings are congregated together, and in every city it is one of the most difficult problems we have to contend with and one ever present even under the most sanitary conditions it is possible to maintain; and when we consider the very small amount of the losses from this disease during the present war we can appreciate the wonderful work done by the medical departments of the armies and marvel at their success in maintaining healthful conditions under such adverse circumstances.

PUTTING THE DOCTOR ON HIS OWN RESOURCES

For all the problems so far mentioned the surgeon can prepare himself in advance. But once in a while a brand new problem arises unexpectedly, and has to be dealt with unexpectedly. This is where the capacity of the medical service gets its real test.

Such a problem would be the outbreak of a previously unknown disease, with the consequent necessity for learning how contagion was effected, and for doing whatever might seem possible to cure and to effect prevention pending the obtaining of definite information on which to base action. This very situation arose in a measure in the epidemic of influenza; but this was merely the recurrence of an old though still imperfectly understood malady, rather than the incidence of something absolutely new. A much clearer case of the latter condition dates back to the first winter of the war.

It was out of the question to keep the trenches dry; and of course it was absurd to think of keeping them warm. It was therefore impossible to avoid the necessity for the soldiers' standing, sometimes for hours on a stretch, in half-frozen mud or water. Under the circumstances it was anticipated that a fair amount of frost-bite would be encountered, and the doctors were prepared to deal with it. But they found that their expectations were totally inadequate. "Frost-bite" appeared almost as an epidemic, with unwonted severity that often led to amputation and complete disability, and with other features forcing the medical men to recognize it as a new or at least a vastly exaggerated phenomenon.

As early as the late summer of 1915 the thing was discussed with some approach to accuracy in the medical papers. The affliction was characterized by swelling, pain and disturbance of sensation in the foot, but was free from the necrosis or death of tissue that accompanies true frost-bite. The names frigorism and frigidism were suggested for it, but the Tommy beat the doctors to it with the name of "trench-foot," which stuck. It was early established that the particular thing responsible for the trouble was the combination of cold and wet with the interference with circulation in the leg and foot by tight puttees and boots. A very thin layer of moderately dry air between the skin and the external cold water or ice enabled the heat of the circulating blood to keep the parts warm enough to prevent the trouble; and this condition was secured by wearing bags of soft, thin oilskin on the lower limbs, in conjunction with woolen socks. Above all nothing tight must be worn about the leg.

WHEN FEET GET MOLDY

During ensuing winters, however, the repetition of trench-foot on a disconcerting scale led to further study, and it was made appar-

ent that, at least in the worst cases, there was another contributing cause. This might have been suspected from the first, since many of the severe cases occurred at temperatures considerably above the freezing. It turned out that the trouble was due largely to the action of parasitic fungi, not unlike those which cause bread and meat to become covered with mold. In other words the feet get moldy from exposure to damp and cold.

Every one who has had a touch of frostbite or chilblains knows the discomfort of the first symptoms of swelling and itching, followed by blisters. If the malady is allowed to progress, the blister is followed by a foul ulcer, or the skin will crack and perhaps bleed. On the other hand, many skins crack badly, without other symptoms, on exposure to cold. If in either of these states the foot comes in contact with mud containing the tiny fungus in question, the latter penetrates through the break in the skin, and secretes itself in the tissues. It is alleged to be particularly partial to a location just at the roots of the toe-nails. Here, provided the temperature be suitable, it proceeds to develop with great rapidity. The fungi which cause all the trouble are to be found in straw, manure and stable bedding, so the suggestion is immediate that the parasite was originally introduced into the trenches through the medium of horses and mules. Treatment, of course, is simple once the true nature of the malady is realized.

THE HORSE HOSPITAL

The Veterinary at the Front Is Called Upon to Do Work Which Is Well Entitled to Rank Beside That Performed by the Regular Surgeon

TIME was when, in making war upon what we must now recognize as an altogether trivial and vastly inefficient scale, a very slight injury to horse or mule was ground for his retirement from the service, either by infliction of the death penalty or by the less severe punishment of abandonment. Even as late as 1870, when Europe was last the scene of conflict between first-class powers, human surgery was in a very elementary condition as compared with its present high estate, and of animal surgery next to nothing was known or cared. Horses were plentiful, and to cut the Gordian knot presented by a gunshot wound in an equine flank or leg with the aid of a firing squad and a few well chosen words about putting the poor brute out of his misery was alike cheaper and easier than to attempt its unraveling by any method calculated to restore the unfortunate animal to a state of usefulness.

To-day the horse has established his claim to better consideration. We read on every hand of the motorized artillery, motorized infantry, motorized transport; we are told that during the great German withdrawal cavalry action took place for the first time since the Boche dug himself in after the Battle of the Marne; and from all this we are perhaps prone to conclude that in this war the horse played little part. The fact is, however, that the World War, while evidencing the wonderful mechanical progress of our era, threw the horse into unexpected prominence. When it is considered that each army corps, on a war footing, comprises tens of thousands of horses, it will be readily understood that the total number of those used by all belligerents should amount to some millions. In face of the incalculable enlargement of the whole scheme of warfare, the internal combustion engine was powerless to displace the horse, powerless to do anything more than fill the great gap left between the supply of animals and the demand for power. Like everything else, horses and mules were found in this war in numbers never before approached.

And, as it was necessary to exercise greater and greater scrutiny of all resources, so, too, it was essential that the ultimate pound of energy be obtained from every animal, that no mount or beast of burden be permitted to

go into the last discard until every expedient to save him had been exhausted. For horses were scarce; no longer could the army chief shoot them or work them to death or turn them off with calm confidence that plenty more were to be had. Rather he conserved them in every possible way; and so we had the field hospital for horses.

HANDLING WOUNDED HORSES

The first adjunct of an ordinary hospital, the avenue through which it is supplied with its raw material, is the ambulance. Now a wounded horse or mule is just like a wounded man; sometimes he can proceed to the nearest relief station under his own steam, and sometimes he must be carried to the operating table. So connected with the horse hospitals at the front we find, sure enough, special horse ambulances. These were hardly so efficient as the more accustomed conveyances for human soldiers, in that the bulk of a horse, and the equine tendency to signalize all physical or mental anguish by means of flying hoofs, made it possible to accommodate but one passenger per trip. But wounded horses were not brought out of such desperate places as were wounded men, nor in such quantities; so this drawback was seldom found to be a serious one.

Once delivered to the hospital and turned over to the doctors, the first consideration was how the horse would behave under whatever treatment his injuries might call for. In the case of human patients this question was disposed of by the use of anesthetics. But a horse would kick up quite as much fuss at being chloroformed as he would at being operated upon; and besides, it was not customary to consider his feelings quite so carefully as those of a man. So while certain operations called for a local anesthesia which was conveniently obtained by means of a cocaine solution, for the most part the wounded horse was tied up in such a manner that he could not kick and could not jerk the affected region away from the surgeon's hands, and the work of patching him up proceeded. If the reader will but reflect that even so simple an operation as shoeing gets upon the nerves of many horses to the extent of making it necessary to restrain them, he will realize that it was not always a simple matter to render a horse sufficiently helpless so that knife and needle might safely be used upon him.

No exact statement can be made as to the scope of the operations which were performed successfully upon the patients of this equine hospital. The same difficulties that make it the custom in civil life to shoot a horse with a broken leg were met at the front. The only difference is that there the value of a live animal was so much greater and the technique of treatment so much a part of the day's work that means could profitably be employed for saving him and hastening his recovery which ordinarily would cost too much in labor and expense. Still the big part of the work done in the horse hospital was necessarily in connection with flesh wounds, and it was in the means for successfully coping with these and preventing infection that the novel service made its greatest strides.

In order, first, to sum up the main tasks performed by the veterinary surgeon behind the battle front, it may be said that by staying the bleeding of recent wounds, he was able to save the life of a great many horses. Again, in the case of epidemics, he had to diagnose the complaint and take such measures as were required in order to remove the infected animals. The discovery of glanders may even be called a vital question for the army, this terrible disease being transferable to man, even though the epidermis be intact. Any horses responding to the Malleine test were, therefore, killed and dissected immediately, thus controlling the disease and insuring the maintenance of sufficient numbers of these animals.

WHAT A VETERINARY HOSPITAL INVOLVES

The horse hospital was to be found on both sides of the long thin line that stretched across Belgium and France, dividing the hostile forces. Thus a German establishment, of which we chance to have particulars, was described as consisting of the following units:

The reception stable, accommodating sixty horses, where all the horses coming from the front were kept until received in the proper ward. Here they were submitted to the Malleine test, as well as to blood tests.

A stable for patients suffering from infec-

tious lung diseases, which afforded room for eighty horses.

A shed comprising several sections, respectively, for horses suffering from glanders, suspected of infection with glanders, and afflicted with mange.

Three stables for surgical patients, accommodating 140, 140 and 80 horses, respectively.

A stable for officers' horses, mares in foal, and mares and foals, as well as for cured horses, ready to be released.

There were also available three race courses, one of which was resorted to whenever the reception stable did not suffice to cope with actual requirements, while the two others were used to give healthy horses an airing. Finally, there was a farrier's shop, the chief veterinary's office, a chemist's shop and a laboratory. The men and non-commissioned officers were housed in barracks of their own, where was also the commander's office.

The staff comprised the chief veterinary surgeon, three veterinaries and two assistant veterinaries, each of whom was assisted by two men trained for the veterinary sanitation service, and a farrier. Each veterinary had under his charge at least 100 patients.

The general treatment and surgical operations in the horse hospital were superintended by the chief veterinary. Horses affected with glanders were killed and dissected immediately; those suspected of this terrible malady were isolated and subjected to a renewed Malleine test. Horses suffering from incurable external disease, if free from fever, were, in Germany, handed over to the horse slaughterer; those with fever were killed and turned over to the flayer in order that, if their flesh could not be eaten, at least their hide might not be wasted. A board installed near each horse's manger indicated its date of reception and sort of complaint. Much care was bestowed on keeping the horses' skin, hoofs and legs in proper condition, as well as on cleanliness, ventilation and disinfection of the stables. Each horse had a watering bucket of its own. Patients likely to remain at the hospital for some length of time were deprived of their horseshoes and, if required, were given a daily airing. Pregnant mares, mares with foals, and jaded horses were allowed a long rest every day on the grounds close to the hospital. Flaked oats was used extensively in feeding emaciated horses.

Just as is the case with the human sufferer, a horse was not ready for discharge immediately upon the conclusion of the operation. A period of convalescence followed, during which the wound had to be kept under observation, maintained in aseptic condition, etc.; and the processes and tools used here were substantially the same as those employed for the analogous work upon men. Further, if the nature of the case so demanded, measures for restoring the patient's strength to normal were likewise in order, so that in this as in the more accustomed variety of hospital, the convalescent ward was a feature.

It must not be forgotten that the work of the regular field hospital was not confined to cases of actual wounding. Men get typhoid in spite of every possible precaution; exposure leads to pneumonia or the development of constitutional disorders; dysentery and other digestive or nutritive troubles will occur in the best regulated armies. All these must be taken care of in the hospital. The boast that death from preventable causes not directly connected with wounds received in action has been practically eliminated from the modern army is made possible first of course by prevention measures, but second only to these by the excellent hospital facilities which cure a sufferer instead of leaving him to die in his tent. So, too, horses will get the mange, will come down with one or another of the epizoötic or casual ills to which horseflesh is heir. These incidents furnish a secondary field of activity for the horse hospital, and a very important one.

By employing all the available resources, a veterinary hospital was able to cure a considerable number of invalid horses and, by surgical operations, to make a great many wounded ones fit again for war use, which otherwise would unavoidably be doomed to death at the slaughterer's hand or by a welcome bullet. Those cured were, by a proper treatment, made suitable again for heavy service, thus filling any gaps and restoring to each detachment their own horses, a practice bound to make for increased fighting fitness. Considerable values were in this way saved, and veterinary surgeons were enabled to increase their stock of professional experience.